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A REVIEW OF THE PARASITIC CRUSTACEA OF THE GENUS ARGULUS IN THE COLLECTIONS OF THE UNITED STATES NATIONAL MUSEUM[1]

By O. Lloyd Meehean

The copepods of the family Argulidae, popularly known as fish-lice, are of economic importance in that they cause serious depredations on fish populations of confined environments. Whole pools and lakes have been depopulated as a result of their attacks. On the other hand, under ordinary conditions these animals may be very inconspicuous with their depressed bodies flattened tightly against those of their hosts. They inhabit the gill cavities, the edges of the eyes, the base of the fins, and other tender portions of the fish's body.

Wilson (1902) first brought together the literature and descriptions of American and other species. Since that time he has described a number of species in various periodicals, and many other descriptions of new species have accumulated. At the present time, however, it is with great difficulty that a specimen may be identified unless one is familiar with all the species. Usually it is necessary to have an adult male to be positive of correct identification. Meanwhile, already known species are being redescribed as new because of the meagerness and incompleteness of the original descriptions. It is hoped that by the use of this paper identification may be facilitated, and it is the intention to bring the literature and knowledge of American species together.

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The argulids in the United States National Museum have been examined, as well as some from other sources. In cases where synonymy was suspected, specimens of both species were examined before any decision was made. Dr. Waldo L. Schmitt and Clarence R. Shoemaker, of the staff at the Museum, were more than kind in their efforts to facilitate the completion of the work. The latter was especially helpful in the final preparation of the manuscript. The American Museum of Natural History lent me the type specimen of *Argulus ingens* for study. Dr. C. B. Wilson gave considerable assistance in many ways, including the loan of specimens of *A. japonicus*. Examples of this same species were sent to me from Japan by Dr. T. Tokioka, of the Mitsui Institute of Marine Biology, and by Dr. Watanabe, College of Fisheries, Hakodate, Japan. Dr. A. S. Pearse lent me a number of specimens. The Bass Biological Station at Englewood, Fla., lent me specimens of *A. varians* for comparative purposes, and specimens were received from one or two other sources.

One new species, *Argulus floridensis*, is here described. The types have been deposited in the collections of the National Museum.

MORPHOLOGY

For the purpose of description, it is necessary to designate the appendages by name, but there is some confusion in the literature in regard to the proper nomenclature. It is felt therefore that some premise should be made for the application of the names used here.

Considerable controversy surrounds the occurrence of a pair of appendages in the proboscis. Claus (1875) expressed the view that the other pair of "appendages" in the proboscis were maxillae. Wilson supports him in this. Grobben (1908) made dissections and cross sections of the proboscis and showed that the so-called appendages were really outgrowths of the lower lip and could not be true appendages. Martin (1932) studied the development of the embryo and found no maxillae in the proboscis, but there was a pair of outgrowths on the lower lip with hollow spines on them, which she called labial spines.

In some instances it seems that the true mandibles have been confused with maxillae. Shortly before ecdysis the exoskeleton loosens, leaving the mandible on the inside. In such a case one structure is the exact duplicate of the other. This is common on mature specimens. An examination of cleared and other specimens from a number of species has shown that Grobben and Martin are probably correct, since no maxillae could be found. Labial spines are almost always seen, sometimes projecting from the opening of the buccal cavity.

Martin has shown that the development of the buccal cavity is from the basal segments of the mandibles and the lower and upper lips. Reason indicates that the maxillae would have to develop between the upper and the lower lip in order to be in the proboscis. This would be contrary to maxillary development in other Crustacea where the maxillae lie behind the under lip. On the Caligoidea the first maxillae are near the base and lateral to the second antennae, and the second maxillae are at the sides of the suctorial tube.

Scott and Scott (1913) state that in copepods the various appendages develop in regular order and in the parasitic forms may then degenerate. These appendages include two pairs of maxillae and a pair of maxillipeds. No one has shown in a satisfactory manner that all these ever occur on argulids. On the basis of the above evidence it was decided that the two pairs of appendages between the mandibles and the first swimming legs should be called maxillae, with only the mandibles in the buccal cavity.

Among the argulids the body is depressed, as a result of adaptation to their parasitic existence on the external surface or in the gill cavities of fishes. The carapace (fig. 21, *b*) is composed of lateral lobes or alae, which originate as folds of the posterior region of the cephalon and are fused to the dorsal surface of the first segment of the thorax. Dorsally the cephalon proper is separated from the first thoracic segment by a transverse groove. Extending obliquely from this groove on each side is a ridge, which sets off the cephalic area and more distally extends outward on the carapace as a groove ending at the edge in a slight sinus.

Extending forward from the transverse groove on the middorsal surface of the carapace is a pair of ridges lying close together, the dorsal ridges, which pass between the eyes and end some distance forward. They may either be parallel or bow toward each other just posterior to the eyes and away from each other just ahead of the eyes. A median "nauplius eye" may be seen between the ridges just anterior to a transverse groove or ridge some distance posterior to the compound eyes. On two American fresh-water species the dorsal ridges are branched at the anterior end; others are simple.

The alae extend backward over the thorax, leaving a sinus that exposes the three free thoracic segments between them. These lobes may extend to the third swimming legs or far enough back partially to cover the abdomen. They may partly close the sinus by overlapping slightly, as on some species where the alae extend over the abdomen, or they may flare out leaving the sides of the sinus diverging.

The abdomen is unsegmented and bilobed at the posterior end, forming the anal sinus. The anus is found at the base of this sinus, while somewhere along the inner edges is a pair of anal furcae.

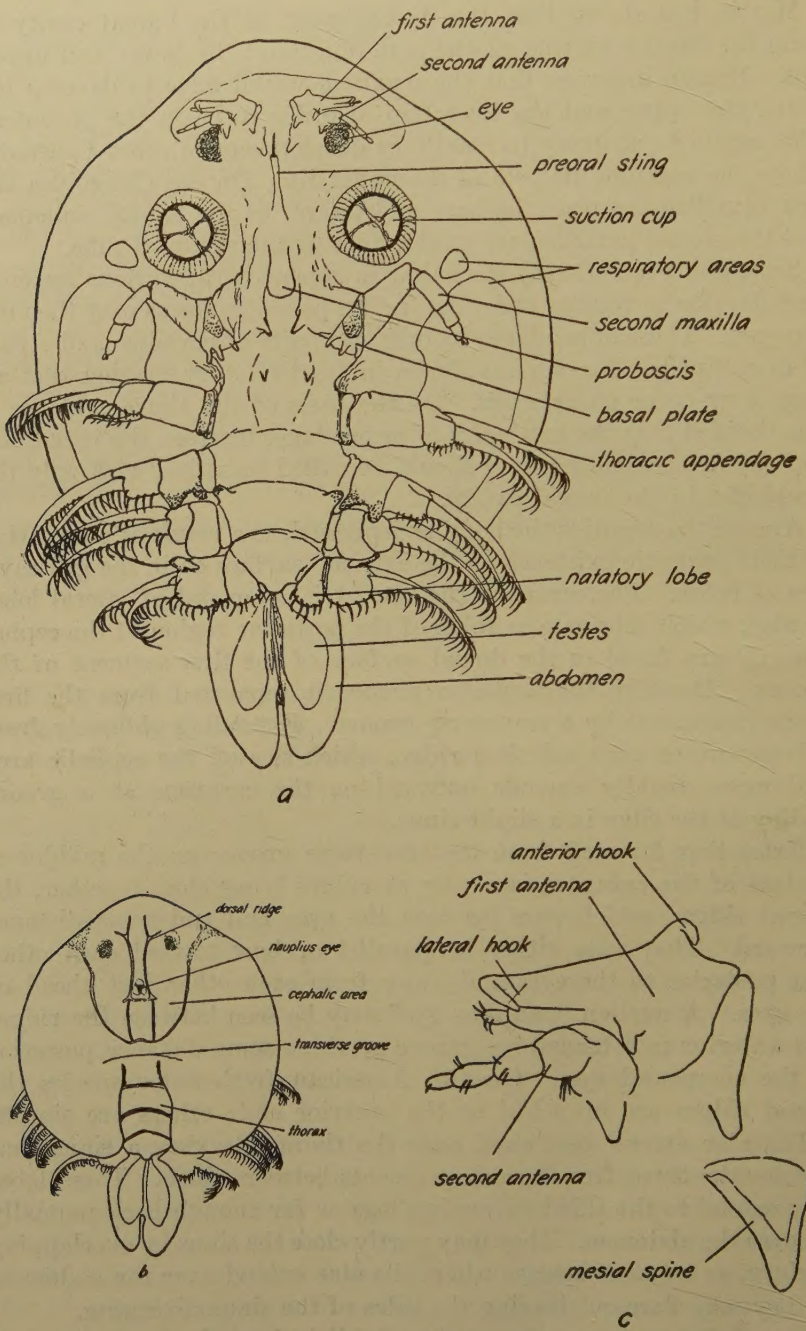

FIGURE 21.—*a, Argulus japonicus,* male, ventral view; *b,* same, dorsal view; *c,* antennae of *Argulus pugettensis.*

On the ventral side the various appendages can be seen (fig. 21, *a*). On the anterior end of the body are two pairs of antennae. The first segment of the anterior pair is chitinized, sometimes with a spine at the base. The second segment is enlarged and prolonged into a lateral hook. On the anterior surface of the hook there may be a fingerlike prolongation with or without another anterior hook. In a few instances this may be a mere knob or almost missing. Often there is also a ventral spine on the posterior surface of the hook mesial to the base of the flagellum which extends to about the length of the lateral hook (fig. 21, *c*).

On the second antennae the proximal segments are enlarged, usually with a spine at the base. The distal segments are slenderer and considerably longer than those of the first antennae. Near the midline of the body just posterior to the antennae is another pair of spines, the postantennal spines. All these spines will be used in identification.

According to Martin (1932) the spine sometimes seen on the interior of the lateral hook will become the exoskeleton after ecdysis. The end of the hook is perforated with a gradually widening canal leading back to a chitin-lined sac thrown into many folds with a large number of chitinous hairs. It is probably gustatory in function.

In the longitudinal groove running forward mesially between the antennae is a preoral sting, which is retractile into a sheath and at the base of which is a poison gland. Posterior to this sting is the proboscis, which also lies in the groove when at rest but which is erected at right angles to the body when functioning. It is a cylindrical bulbous structure somewhat larger in size than the sting and carries the true mouth. The framework is of chitinous bars, which enclose the buccal cavity and extend into the proboscis.

The buccal cavity is formed by the delicate upper lip and the more bulbous lower lip. The anterior portion of the buccal cavity contains a pair of swellings ending in hollow spines, the labial spines. They come in contact with the host first. Martin has shown that very early in embryonic life these develop from the lower lip.

The mandibles project from the sides and are completely enclosed by the buccal cavity when at rest. The basal segments of the mandibles assist in the formation of the proboscis in a very early embryonic stage by fusion of the distal portions of the basal segments with the lips. In this way the upper and lower lips form the dorsal and ventral walls, and the mandibles the lateral walls, of the buccal cavity.

The suction cups, or so-called sucking disks, develop from the maxillae on each side of the preoral sting. They have a flat rim covered by a chitinous exoskeleton with thickenings like ribs radiating

outward. These ribs are variously broken up into segments, which are more or less characteristic for a given species. They may be a series of long or short rods (fig. 26, *c*), segments simulating imbricate plates (fig. 27, *a*), or an elongate segment followed by a series of overlapping plates (fig. 22, *b*). The number of plates in the ribs varies only slightly for a given species. They will be used for identification purposes.

The next pair of appendages constitutes the second maxillae. They have a triangular plate on the basal segment, which is divided posteriorly into three teeth or lobes (fig. 26, *a*). The shape of these is more or less constant for the species. On each side of the midline of the body at the base of this appendage is a pair of spines, and posterior to it, just ahead of the first thoracic appendage, is a second pair. These two pairs of postmaxillary spines will be used along with the teeth of the basal plate to aid in identification. These appendages are considered maxillae because they occur ahead of the tranverse groove separating the head and thorax and have an excretory gland, the so-called maxillary gland at their base, and because no maxillae are found in the buccal cavity as sometimes stated.

The four pairs of thoracic appendages are made up of a protopod, composed of the precoxa, coxa, and basis, and of two rami, the exopod and endopod. The precoxa is very small in most species, but on a few with long appendages it becomes sizable. The two anterior pairs may have a flagellum extending mesially from its point of origin (fig. 38, *d*) on the dorsal side at the base of the exopod.

On the female the thoracic appendages may be modified by having a slight chitinous ridge armed with setae on the posterior ventral surface of the coxa. Almost every species has a boot-shaped or rounded natatory lobe extending from the posterior of the coxa of the last appendage. On the male it may or may not be the same size and shape as that of the female of the same species.

On the male the second, third, and fourth appendages are modified for copulation. These specific modifications have hitherto been used as practically the only positive means of identification. On the ventral posterior axis of the second appendage is usually found a bilobed prominence extending the full length of the coxa. It may be variously modified or be entirely lacking. This structure is usually covered with chitinous spines, which are very often truncate.

Typically the coxa or basis of the third appendage is modified on posterior surface by the formation of the socket (fig. 32, *c*), the so-called "semen capsule" or "semen pocket" of many authors. This is formed by a fold of tissue from the posterior or ventral side of the appendage turned toward the dorsum to produce a pocket. From the ventral side it appears as a rounded or oblong lobe projecting backward and overlaps the "peg" on the next appendage. From

above, the opening is oblong or round and approximately the length of the fold, usually with two elongate papillae forming a groove perpendicular to the axis of the appendage and directed toward the opening. The opening is shaped and placed according to the structure and shape of the peg on the next appendage.

On the interior of the pocket are three folds, of which the median one is modified for the accommodation of the size of the pocket to fit the peg and according to the size of the appendage of the female that is clasped by this apparatus. There are other types of sockets, which will be described in connection with the species concerned.

The peg on the fourth appendage is located on the distal edge of the anterior surface of the basis near the base of the exopod (fig. 34, *d*). It is variously shaped according to the species. Generally it is some variation of a pear-shaped structure with a narrow tip turned laterally. On the proximal side and ventrally there is a chitinous ridge around the base of the peg extending obliquely across the appendage. It may be covered with very short spines or entirely unarmed.

The peg and socket apparatus is used entirely as a clasping medium. The last appendage of the female is clasped from the dorsal side, and the peg is fitted in the socket, which is enabled to accommodate itself by the folds already described. The accessory organs on the other appendages assist in this process. The abdomen of the male is twisted around that of the female first on one side, then on the other, so that the ejaculatory duct, located ventrally between the legs at the posterior end of the thorax, is brought directly in contact with the spermathecae of the female. These are located on the under side of the abdomen close to the thorax.

The testes are a pair of elongate bodies lying on each side of the midline in the abdomen. In the female the ovaries lie in the thorax and the spermathecae appear as small rounded bodies in the anterior end of the abdomen, often with a pair of tactile papillae projecting posteriorly from near the opening.

Two respiratory areas are located on the ventral surface of the carapace lateral to the body. The smaller of these may be anterior to the larger or may be mesial to and partially surrounded by it. Their function is considered as respiratory, because it has been found that there are blood sinuses under them limited by a single layer of hypodermal cells. In most instances these areas have a characteristic shape for a given species.

The anterior portion of the carapace and a portion of the lateral edges are flattened to fit against the body of the fish. These portions are armed with small spines directed posteriorly. The various ventral portions of the body of the animal that may come in contact with the body of the fish are also armed in the same manner.

CHARACTERS USED IN IDENTIFICATION

In a previous paper (Meehean, 1937) it was mentioned that many of the specific characters used at present for identification are variable in nature. Consequently positive identification is not possible unless mature male specimens are available. For the same reason it is difficult for persons unfamiliar with the actual specimens to know positively whether the species has been described if only the females are at hand. Therefore, it is felt that it would be of value to have some method for identification based upon characters that are more or less constant and that can be used for both sexes. A study of the specimens in the National Museum has shown that certain characters or combinations of characters can be used for this purpose and has indicated that some species are synonymous with others already described when the characters are fitted to them. So far there has been only one exception to the reliability of the characters selected, and it concerns a foreign species of which a more thorough study will be made later when other data are available.

The characters utilized are suitable for all the American fresh-water and salt-water forms. The most important of these are the respiratory areas. Wilson has said many times that they are specific, yet many descriptions have failed not only to figure them but even to mention them. In a few instances they are very similar in closely related species but are always slightly different and when combined with other characters serve to separate the species. Such examples are *maculosus* and *versicolor*. As the characteristic shapes are difficult to describe, they are figured for each species.

The segments making up the ribs on the rim of the suction cups are also specific. Although there is slight variation in the number of segments, the formation is very characteristic. In only two species examined was there any great difference in this respect. The male of *pugettensis* has a smaller number of segments than the female, with a basal segment of a different type. However, one vial containing immature specimens had females with typical segments like the male and stages between the two. Since these chitinous thickenings are known to develop at points of great stress, the difference in the two sexes might be attributed to the fact that the male is much smaller than the female and would probably develop fewer segments. In other instances there is some similarity in the segmentation, but when combined with other characters it loses its significance.

The antennae have characteristic appearances for some species and in many instances help in the identification. The number of spines, the character of their arrangement, and whether a spine or hook is found on the anterior surface of the first antennae are all of assistance.

On the second maxillae the teeth of the basal plate and the two pairs near the midventral line of the body may be characteristic in shape, size, or number.

Finally, the presence or absence of flagella on the swimming appendages, the shape of the swimming lobes on the posterior of the fourth appendages of the female, and other more variable characters may be used at times.

The maximum size as reported for each sex is given. Mature specimens of either sex within a species may vary considerably in this respect, and the sex difference may be great or small. Relative body proportions are not a reliable index for specific determination, since the proportions may change according to size, age, and stage of development. In a general way they do hold for sex comparisons; that is, the carapace may extend farther posteriorly on the male, or the length and width of abdomen or its shape may be different on the two sexes, etc., but on the whole they cannot be relied upon to establish specific identification. Color has been used in many instances, but it too cannot be depended upon as the sole basis or even in combination with proportional measurements for specific determination. All species are American fresh-water forms unless otherwise designated. All figures used are from camera lucida drawings of specimens in the National Museum and from the types where practicable.

SYNONYMY

Certain of the species listed in the literature have proved to be synonymous when studied according to the characters outlined for specific indentification. *A. biramosus* Bere (1931) is identical with *appendiculosus* Wilson (1907). Any differences are merely a matter of size. *A. ingens* Wilson (1912b) is the same as *nobilis* Thiele (1904), as previously stated by Wilson (1924), but there seems to be no reason for maintaining a variety as he has done. *A. canadensis* Wilson (1916) is the same as *A. stizostethii* Kellicott (1880). There are no flagella on the latter, contrary to Wilson (1902), and he failed to note the complete respiratory area.

The male of *A. niger* has never been described, since it is the same as *pugettensis* except that the former is very dark, as its name indicates.

Vial 77810 (old number 60589) in the National Museum contains a male labeled *pugettensis* that is entirely different from the described male of that species and is from Key West, while the species has always been reported on hosts indigenous to the Pacific coast. This specimen has been given the new name *floridensis*. It was collected by A. E. Verrill and dated 1884.

Specimens labeled *A. megalops* var. *spinosus* in the Museum are not different from the regular species except that they are lighter in color; hence the spinous under portion of the body is more conspicuous. Color seems too variable to use in establishing differences. *A. varians*, recently described by Bere from females, is similar to *A. megalops* except for the great variation in the size of the carapace. Four specimens from the Bass Biological Laboratory show these gradations well.

The male of *A. latus* Smith (1873) has never been reported because it is identical with *funduli* Krøyer (1864) so far as the available specimens are concerned.

A. maculosus has been redescribed because no specimen was found to match the original description. The species was figured as having the characters of *americanus*. It was established on the basis of color. However, there are actual specimens of a species that may be considered as representing *maculosus*. As the types in the National Museum proved to be *americanus*, it is necessary to designate new types for *maculosus*.

A. piperatus Wilson (1920a) is identical with males of *A. flavescens* Wilson (1916), as described by Mueller (1936) and as collected by myself in Florida. *A. paulensis* is apparently the same as *A. salminei*, although no specimens of the latter are at hand.

Specimens of *A. japonicus* collected by Dr. Pearse in Japan and those sent me from that country proved to be identical with *A. trilineatus*, thus invalidating another species. There are, therefore, 21 North American, 2 South American, 2 Siamese, and 1 African species available for study in the Museum. These include all the North American species except some undescribed ones that Dr. Wilson has at the present time.

It is suggested that the key be used in combination with the figures of the respiratory areas in order that identification be accurate. The other figures may also be used to advantage, especially those of the male accessory copulatory organs.

DEVELOPMENT

Larval stages have been described for *A. foliaceus*, a European species, and for *A. funduli*, *A. megalops*, *A. americanus*, *A. maculosus*, *A. catostomi*, and *A. stizostethii* from this country. More recently T. Tokioka (1936b) has given a very good account of *A. japonicus*, which is also common in this country. Martin (1932) described the development of the proboscis from the early embryos of *A. viridis* in England. A generalized description of larval development is somewhat as follows:

The eggs are laid on a hard substratum in single or multiple rows and are arranged end to end or at slight angles to each other. As they are laid they are coated with a gelatinous substance that hardens on contact with the water, forming ridges, lumps, or wrinkles over the surface of each egg and is firmly attached to the eggs and substratum.

Batches of 30 up to 500 or 600 may be laid, depending upon the species, and vary in size from 0.375 by 0.25 to 0.64 by 0.43 mm. The period of hatching is somewhat variable. Tokioka found that the eggs of *A. japonicus* hatched in 12 days at 30° C. and in 60 days at 15° C. On the other hand, Wilson noted that *A. americanus* hatched in 18 days at 65° F. and in 17 days at 72° F., while *A. megalops* required 60 days at the same temperature. Kellicott records a period of 81 days for *A. stizostethii* at room temperature. According to Wilson (1907), Clark observed *A. foliaceus* hatching at the end of 5 months 8 days, and 7 months 2 days where the eggs were laid in the fall and hatched the following spring.

Martin's observations on the early embryos throw light on the structure and development of the proboscis. At this time the mandibles are incurved with apices directed anteriorly toward the mouth opening and some distance behind it. The basal segment is large and bears a 3-segmented palp with three rami on the terminal segment.

On later embryos the basal segment has increased in size all out of proportion to the other segments. A rudiment of the lower lip becomes apparent in a position posterior to the mandibles, while the upper lip occurs anteriorly between the bases. Apparently the distal portions of the basal segments fuse with the upper and lower lips to form walls for the buccal cavity. The chitinous framework probably forms along the lines of greatest stress, since there is a great deal of individual variation.

First stage larva.—Larvae of this first stage may be of two kinds—one for the slower-hatching species, which are more fully developed and lack mandibular palps, and another for those that hatch more quickly and are less advanced in development. *A. japonicus* belongs to the latter group and will be used as an example, since the immature stages have been fully described by T. Tokioka as each molt occurred so that a most logical picture of development can be obtained.

The length of the hatching animal is 0.7 to 0.9 mm. Its carapace is oval, with short alae and with all the legs, the thorax, and the abdomen left exposed. Only the groove limiting the cephalic area is apparent. The dorsal ribs are unforked, while the joint behind the nauplius eye is lacking. The carapace, ahead of the brown compound eyes, is fringed with chitinous ciliary processes and a few spinules. Along the whole marginal area are many gland cells and some especially conspicuous ones at the base of the first antennae. The stomach has a simple pair of branches, forked only once.

The antennule is like that of the adult, but the proximal segment is lacking. Behind the antennule is the antenna composed of two basal segments with a spine on the posterior side of each. It has an unsegmented palp on the second segment and a 3-jointed distal portion ending in long plumose setae. The antennae are joined to a transverse chitinous bar on each side of which is a forward process and a backward spine—the postantennal spine of the adult.

A small sting is located at the base of the proboscis, which is essentially the same as that of the adult except that it is very short. The buccal fold is not yet serrated, and there are no labial processes or labial spines. The mandible is pointed, with an acuminate process on the lower margin near the tip, and the mandibular palp is attached by a chitinous framework at the base of the proboscis just behind the antenna. It is unsegmented, almost as long as the antenna, and ends in three long plumose setae. It is supported at the base by a circular framework of chitin, which forms a thickened area with a spine at the point of attachment. This framework serves to support the proboscis by means of the inner longitudinal rod already differentiated and an outer longitudinal rod to be differentiated at the next stage. Thus modified parts of the mandible proper form the supports of the proboscis.

The first maxillae are found on each side of the proboscis. They consist of three segments of which the basal one is bulky. On the tip are two large curved claws, one with three small processes on its anterior margin.

On the posterior distal corner of the basal segment of the 5-jointed second maxilla is a spine corresponding to the middle of the three spines found on the adult. The distal segment is provided with two curved claws and a papilla on the tip. Two pairs of spines are located near the midline of the body as in the adult—the postmaxillary spines.

Only the first pair of thoracic appendages is functional; the others are rudimentary and immobile, each with an unsegmented exopod and endopod. On the first appendage the coxa, basis, exopod, and jointed endopod are complete, but the precoxa is indistinguishable.

The abdomen is only about one-tenth as long as the body and has spinules along the posterior ventral side and margin. The caudal furcae are comparatively large. Sexes can be distinguished by the presence of rudimentary testes or small round seminal receptacles.

Second stage.—After three or four days the first molt takes place, and the animal assumes more the shape of the adult. It attains a length of 0.9 to 1 mm. The anterior margin of the carapace is fringed with ciliary processes as far back as the first maxillae. The

anterior marginal groove on the carapace is distinguishable, and the joint in the dorsal ribs is just discernible.

On the first antennae the proximal segment is faintly defined and has a spine projecting backward, while the third segment has developed a small process with two setae at the end. The palp on the second antenna as well as the spine on the posterior margin of the second segment has disappeared, but a seta has developed on the anterior distal margin. The third segment is still small, the fourth approximately the same as in the previous stage, while the fifth is longest and ends in a number of long setae. Only a pair of post-antennal spines remain where the transverse chitinous bar occurred before the molt.

The mandibular palp has disappeared and the chitinous framework that connected it to the mandible is a simple longitudinal support, but the junction of this rod to the mandible is still thickened into a spine, which gradually disappears with each successive molt. A chitinous thickening occurs on each side of the anterior transverse bar along the buccal fold foreshadowing the serrated margin of the adult. The small labial processes are clearly seen although the labial spines are absent. There is a pair of spines in front of the mouth opening.

The first maxillae consist of four segments by division of the basal segment into two. The more distal of these has two spines on the ventral proximal margin. A spine has developed on the posterior margin of the second maxilla (the inner spine of the adult), and the second segment has become somewhat longer than the more distal ones. Spinules have made their appearance on the ventral side of the thorax, and ramifications of the stomach have become slightly more complex.

All the swimming appendages have assumed the shape of those on the adult and serve as locomotor organs in the place of the antennal and mandibular palps. A number of plumose setae have developed on each. The abdomen is one-seventh to one-sixth as long as the body, with the lobes projected slightly backward and spinules on the margins.

Third stage.—When the larva has reached an age of five to seven days a second molt occurs. The main difference noted between second, third, and fourth stage larvae is in the pattern of the first maxillae, the number of spines on the basal segment of the second maxillae, small differences in size and number of setae and spinules, and in the pattern of the branches of the stomach.

The larva has reached a length of 1.0 to 1.2 mm. Behind the nauplius eye the joint of the dorsal ribs is clearly visible, the posterior transverse bar of the proboscis can be seen, and the buccal fold has a process on its free margin.

The first maxillae have reached the highest point of development as a clasping organ and in the next stages will begin to degenerate. The boundary between the basal and second segments is becoming indistinct, two spines on the second segment have disappeared, and the framework of the suction cup is faintly seen within the basal segment. On the second maxillae a small spine has been added to the basal segment at the posterior distal corner (the outer spine of the adult), and some minute spinules have made their appearance.

A few spinules occur for the first time on the ventral surface in front of the anterior marginal groove and along the margin of the carapace adjacent to the anterior respiratory area. Rudiments of the flagella are formed on the posterior dorsal corner at the base of the exopod of the two anterior pairs of swimming legs. On the female a minute chitinous spine appears at the extremity of the duct of the seminal receptacle.

Fourth stage.—A larva seven to eight days old molts for a third time and has reached a length of 1.2 to 1.4 mm. The lateral lobes of the carapace barely cover the second swimming appendages. Branches of the lateral groove limiting the cephalic area are faintly seen extending inward. The anterior dorsal ribs show a rudimentary outer branch, and the ciliary fringe of the carapace extends as far back as the second maxillae.

Both pairs of antennae are the same as in the previous stage, but the buccal fold of the proboscis has two teeth on the free margin. On the basal segment of the first maxillae there is a considerable expansion due to the formation of the suction cup. The circular margin is fringed with minute triangular processes, and the muscles attached to it can be seen through the chitinous exoskeleton. Buds of the flagella on the first two pairs of thoracic appendages are still very small and without any setae. On the male the posterior side of the joint between the coxa and basis of the third leg is deeply cut where it foreshadows the socket of the adult. The abdomen of the female is slightly smaller than that of the male.

Fifth stage.—Three to four days after the third ecdysis a fourth molt occurs, and the larva reaches 1.3 to 1.7 mm. in length. The outer branches of the dorsal ribs are still short and the ciliated margin of the carapace has extended almost to the first thoracic segment.

The two basal segments of the second antennae have several setae on the distal end. The third segment is small, the fourth twice as long as the third, with the two setae that occurred on the segment in the preceding stages moved to the distal end. The last segment is as long as the fourth and is tipped with a few rather thick setae.

The labial spines are distinctly located on the floor of the buccal cavity. Important changes have also occurred in the first maxillae.

The basal segment has broken and the suction cup is exposed, although the remaining segments are still intact. The suction cup is exactly the same as that of the adult except that the number of segments in the chitinous ribs supporting the margin is smaller. Each rib is composed of one long and two short segments, with the distal one only faintly defined. The basal segments of the second maxillae have two long setae in the middle of the posterior margin of the scaled area besides many scales on the surface.

The branches of the stomach have become fairly complex. On the first thoracic leg the rudimentary flagellum has two setae while that on the second leg has one. On the ventral posterior edges of the coxa of the second leg of the male the bilobed prominence is laid down. On the third leg the socket is indicated by two lateral folds and a projection on the ventral side that will become the median fold. The precoxa and coxa of each leg have small spinules or scales on the ventral side. The abdominal lobes have grown considerably and the anal sinus reaches about one-fourth the length of the abdomen.

Sixth stage.—The difference between the fifth, sixth, and seventh larval stages is found in the residual portion of the first maxillae and in the degree of development of the male accessory copulatory apparatus. These stages cannot be distinguished in the female because of the great variation in the size.

They have attained a length of 1.6 to 2.0 mm. The residuum of the first maxillae shows no segmentation. On the second and third legs the accessory apparatus is the same, but a rounded prominence has made its appearance on the anterior distal corner of the basis of the fourth leg where the peg of the male will be located. The abdominal processes are faintly defined at the base of the abdomen in the female.

Seventh stage.—The sixth and seventh stages are attained in 10 to 18 days. At this time the animal has reached a length of 2.0 to 2.2 mm. The lobes of the carapace have extended to cover the third legs, and the dorsal ribs are distinctly forked. On the first maxillae the residual degenerating portion consists of a small process provided with a minute spinule, while the ribs of the suction cups have added a short segment.

On the first two swimming legs the flagella have become longer and reach beyond the proximal margin of the basis. They are provided with several plumose setae. On the male the bilobed protuberances of the coxae of the second legs are fairly conspicuous, and the socket of the third pair is almost complete, although the papillated processes in front of the aperture are not yet apparent. On the fourth leg the peg is almost like that of the adult. It is provided with a lobed process on the ventral side, and the tip ends in

a terminal chitinous process with a small spinule. The chitinous framework supporting the peg continues to the posterior proximal edge of the basis across the dorsal side of the segment, where the chitin is thickened conspicuously. On the female the posterior portion of the coxa of this appendage protrudes and will be the natatory lobe of the adult.

The abdomen differs in shape with the sexes. On the male the lobes are larger and bluntly pointed while the smaller ones of the female are rounded.

After the seventh stage there is no well-defined characteristic; the change brought about by molting is merely in grade. The earlier stages are very regular, but the later stages, after the fourth, are very irregular and hard to define.

Molting takes place by rupture of the exoskeleton along the midline from the anterior marginal groove to the anterior thoracic segments. The animal draws out the thorax and abdomen through this slit first. Then the anterior portion of the carapace is withdrawn and finally the lateral lobes. This ecdysis occurs over the whole body except the coat of the suction cups, which comes off after the molting process of the other portions is through.

Subsequent development.—From this time on the lateral lobes of the carapace enlarge, and all the grooves on the dorsal surface become distinct while the longitudinal groove appears later. The ramifications of the stomach become more complicated, and pigment spots on the oviduct appear about the twentieth day after hatching. The suction cup loses the residual portion of the maxilla except a tiny seta, which remains for a long time. A papillated process on the anterior margin of the precoxa of the third leg and small processes in front of the aperture of the socket of the male are formed at a later stage.

The abdomen grows somewhat and the animals become sexually mature during these molts. Development is completed about one month after hatching.

It will be noted that the account by Tokioka describes seven well-defined larval stages with subsequent molts, which serve to bring the animal to sexual maturity. Wilson was indefinite as to the number of molts, but in one place indicated that he had observed four. It is also worthy of note that no mention is made of any maxillae within the proboscis and that the two pairs of appendages immediately behind the proboscis are called first and second maxillae.

Family ARGULIDAE

Genus ARGULUS Müller

KEY TO THE SPECIES OF ARGULUS

a^1. Anterior respiratory area prolonged laterally around posterior one (club shaped).

b^1. Teeth of basal plate of second maxillae sharp, widely separated; suction cups supported by about 10 to 12 plates plus an elongate segment; posterior swimming lobe of fourth appendage on female rounded, abbreviated on male; fresh water ..... stizostethii (p. 479)

b^2. Teeth of basal plate of second maxillae blunt, postmaxillary spine small and blunt; flagella present on first two swimming appendages; suction cups supported by 4 to 6 plates plus an elongate segment; respiratory area relatively narrow; posterior swimming lobe on female prolonged into a fingerlike projection, only slightly prolonged on male; fresh water, Siam ..... siamensis (p. 482)

a^2. Smaller respiratory area anterior, mesial, or in an anteromesial notch of larger area.

b^1. Entire smaller respiratory area anterior to larger.

c^1. Teeth on basal plate of second maxillae sharp, distal one more widely separated than other two; ribs of suction cups composed of 10 to 12 plates and an elongate segment; carapace just reaching third thoracic appendages; anterior hook on antennae slight or lacking, second antennae long; last thoracic segment very wide, flaring over abdomen; brackish and salt water ..... alosae (p. 481)

c^2. Basal plate of second maxillae lobed or with slender blunt teeth.

d^1. Tips of maxillary teeth blunt, but plate not lobed.

e^1. Ribs of suction cups supported by rods.

f^1. Ribs of suction cups composed of 3 rods; knob or hook lacking on anterior surface of first antennae; swimming lobe of fourth appendages boot-shaped, heel pressed against end of thorax, toe extending to or beyond edge of abdomen; whole body appearing circular; anterior respiratory area minute, posterior one very large and oblong; salt water, Siam, Java ..... indicus (p. 483)

f^2. Supports of suction cups composed of 4 to 6 rods, distal ones may be compressed; anterior hook present on antennae, a seta two-thirds as long as two distal segments of second antennae, and opposing them, a long seta opposing tip of first antennae; slight posterior lobe on fourth appendages rounded or faintly boot-shaped; fresh water ..... flavescens (p. 484)

e^2. Suction cups supported only by imbricate plates or by plates and a long basal segment.

f^1. Suction cups supported only by imbricate plates; spine at base of first antennae and near midline of body (postantennal) broad and blunt.

g^1. Plates of supporting ribs numbering up to 30 or more; knob present on anterior surface of first antennae; second maxillae slender; salt water, Pacific coast_____ melanostictus (p. 487)

g^2. Plates in supports numbering about 15 to 20; carapace reaching abdomen; anterior hook present on first antennae.

h^1. First two swimming appendages with flagella; second maxillae short and stout with spinous pads on ventral surface, postmaxillary spines short and truncate; antennae short; salt water, Pacific coast_____ ♀ pugettensis (p. 487)

h^2. First two swimming appendages without flagella; second maxillae about normal in size, proximal tooth on basal plate broader, two pairs of postmaxillary spines not truncate; second antennae longer; salt water, Key West___ floridensis (p. 489)

f^2. Suction cups supported by an elongate proximal segment and imbricate plates.

g^1. First two pairs of swimming appendages without flagella.

h^1. Respiratory areas small and widely separated; proximal segment in ribs of suction cups elongate and narrow; posterior lobe of fourth appendages of female somewhat bilobed; anterior knob present on first antennae; salt water, British Columbia_____ borealis (p. 490)

h^2. Respiratory areas normal (one large and one small).

i^1. Maxillary spines about alike, posterior respiratory area large and irregular in shape; swimming lobe on posterior surface of fourth appendages boot-shaped on female; salt water_____ megalops (p. 492)

i^2. Lateral spine on basal plate of second maxillae blunt, other two more pointed; anal sinus deep.

j^1. Suction cups occupying almost full width of carapace, supporting ribs composed of 6 to 10 imbricate plates and a rectangular basal segment; spine on ventral surface of hook inconspicuous, all others broad; posterior respiratory area reaching close to anterior one and about same width for its full length; salt water_____ bicolor (p. 517)

j^2. Suction cups normal, supporting ribs composed of 6 or 7 imbricate plates (12 to 14 on female) with rectangular basal segment; spine on ventral surface of hook prominent, postantennal spines larger than others; posterior respiratory area some distance from anterior one, anterior half narrower than posterior portion; salt water_____ fuscus (p. 518)

g^2. First two pairs of swimming appendages with flagella.

h^1. Conspicuous anterior hook on first antennae, antennae short, broad spine at base of first antennae and broad postantennal spine; second maxillae broad and short with spinous pads over ventral surface, postmaxillary spines short and truncate, anterior pair on papillae; salt water, Pacific coast_____ ♂ pugettensis (p. 487)

h^2. Knob present on anterior surface of first antennae; dorsal ridges branched at anterior end; posterior respiratory area somewhat reniform; fresh water, universal_____ japonicus (p. 494)

d^2. Basal plate of second maxillae lobed.

e^1. Lobes of second maxillae truncate; hook present on anterior surface of first antennae; supporting ribs of suction cups composed of rods.

f^1. Lobes of second maxillae appearing worn, postmaxillary spines truncate and inconspicuous, anterior knob on first antennae long and fingerlike, with slight anterior hook; supports of suction cups composed of 3 straight rods; salt water_____ laticauda (p. 495)

f^2. Basal plate of second maxillae with truncate or rounded teeth, postmaxillary spines conspicuous; supports of suction cups composed of 4 or 5 rods; posterior respiratory area reniform, anterior hook on first antennae stout; fresh water, Congo River, Africa_____ reticulatus (p. 497)

e^2. Lobes of second maxillae not truncate.

f^1. Two pairs of postmaxillary spines missing, proximal lobe of basal plate more distinctly separated than the one or two lateral ones; respiratory areas small and widely separated; suction cups with about 16 plates in supporting ribs with a proximal plate slightly longer than the others; anterior knob of antennae almost wanting; swimming appendages without flagella; salt water, New Orleans to New Brunswick_____ funduli (p. 498)

f^2. Two pairs of postmaxillary spines present.

g^1. Lobes of second maxillae and postmaxillary spines very broad with spinous papillae on them; supports of suction cups with one long and one oblong rod; spines at base of first antennae and postantennal spines extremely broad and blunt, anterior hook broad at base and very long; anterior respiratory area very small and posterior one extremely long; fresh water, Uruguay_____ violaceus (p. 500)

g^2. Edge of basal plate of second maxillae with broadly rounded lobes, mesial lobe somewhat more prominent, postmaxillary spines very blunt and short; knob present on anterior surface of first antennae, distal segment opposed by a spine, second antennae without much enlargement of basal segments,

spines slight or indicated by protuberances at base of first antennae as are the postantennal spines; supporting ribs of suction cups tapering, composed of 9 or 10 segments; fresh water, Brazil---- salminei (p. 502)

b^2. Smaller respiratory area mesial to larger or in an anteromesial notch of latter.

c^1. Spine present at the base of first antennae.

d^1. Three spines in a row on each side of midline of body, including those at base of first antennae.

e^1. Smaller respiratory area located anteromesially in a notch of the larger one, both posterior to the second maxillae; supporting ribs of suction cups composed of 2 or 3 segments; distal lobe on basal plate of second maxillae blunter and wider than others; basal segment of first antennae usually prolonged into a knob directed toward the midline of body; fresh water. americanus (p. 504)

e^2. Smaller respiratory area in a notch proximal to and some distance behind anterior end of larger; supporting ribs of suction cups composed of more than 2 segments.

f^1. Second maxillae with slender teeth of basal plate widely spaced; first segment of supporting ribs of suction cups elongate and narrow followed by 2 or 3 oblong ones; knob present on anterior surface of first antennae; carapace reaching abdomen; abdomen subtriangular; fresh water---------- versicolor (p. 505)

f^2. Teeth of basal plate on second maxillae close together and long; supporting ribs of suction cups composed of a rectangular basal and 2 distal segments in male and 4 to 7 in female; anterior hook present on first antennae; carapace extending to third appendages; abdomen somewhat rectangular; fresh water. maculosus (p. 507)

d^2. Postantennal spines 2, suction cups with about 5 slender segments in ribs extending two-thirds of width of rim of disk; lateral hook of first antennae curved in an arc, tip of first antennae biramous; postmaxillary spines very small; broad posterior lamellae on basis and coxa of fourth thoracic appendages; animal characteristically broad and leaflike in appearance; fresh water. mississippiensis (p. 509)

c^2. No spine at base of first antennae.

d^1. Basal plate of second maxillae lobed or with slender blunt teeth; no spine on ventral surface of first antennae or at base of first or second antennae.

e^1. Basal plate of second maxillae with 2 to 4 lobes, usually 3, postmaxillary spines absent; anterior knob present on first antennae; ribs of suction cups with 7 to 9 short rods, fresh water---------- castostomi (p. 511)

e^2. Three slender blunt teeth on basal plate of second maxillae; only a slight indication of a knob on the anterior surface of the first antennae, tip of flagellum biramous;

suction cups supported by 2 long segments in ribs; dorsal ridges of carapace branched at the anterior end; fresh water---------- appendiculosus (p. 512)

d^2. Teeth of second maxillae very sharp; no spine at base of first antennae; ribs of suction cups composed of rods.

e^1. Ribs of suction cups with 8 or 9 rods: lateral hook of first antennae short but curved back on itself; fresh water---------- lepidostei (p. 514)

e^2. Ribs of suction cups with about 12 to 18 rods; tip of first antennae biramous, with one of the branches biramous; abdomen heart-shaped in female, with lateral projections on the anterior edges in male; fingerlike protuberances on distal anterior end of first segment of endopod on third and fourth thoracic appendages; fresh water---------- nobilis (p. 515)

ARGULUS STIZOSTETHII Kellicott

FIGURE 22

Argulus stizostethii KELLICOTT, 1880, p. 53.—WILSON, 1902, p. 713, pl. 17.
Argulus canadensis WILSON, 1916, p. 348, pl. 60; 1936a, p. 355, figs. 1–9.

Carapace elliptical, reaching to second or third swimming appendages, sinus shallow; cephalic area prominent, projecting slightly anteriorly. Abdomen somewhat elongate with sides parallel, anal sinus deep, tips of abdomen pointed and diverging somewhat, anal furcae basal. The respiratory areas are peculiar in that the anterior one is prolonged laterally around the posterior one in such a way as to be club-shaped instead of rounded (fig. 22, *a*). As the type of *canadensis* has a very broad mesial respiratory area, the inner edge may easily have been overlooked by Wilson in his description.

The hook on the anterior surface of the first antennae is tight against the body of the antenna in the type of *canadensis* instead of having the usual elongate base; spine present on midventral surface of antennae and at the base. Spines located at the base of the second antennae, near the midline of the body, and the postantennal spines are stouter than the others. The ribs of the suction cups are composed of a stout pedestal with 10 or more apparently imbricate plates (fig. 22, *b*). Second maxillae stout; basal plate large and broad with a large pad; teeth small and sharp, widely separated; two usual pairs of spines are located near the midline of the body but the anterior pair are stouter.

Flagella are lacking on the swimming appendages; female with a small rounded natatory lobe on the posterior surface of the coxa on the fourth appendages; basal segments stout. Second appendages of male (fig. 22, *c*) with the usual bilobed flap on the coxa. Basis of third appendages much abbreviated, with a papilla across the ante-

rior surface; distal end of coxa has a larger papilla parallel to that of the basis so that there appear to be two ridges across the anterior side near the origin of the rami; the coxa is widened somewhat to a point near the middle, but no enlargement is formed for the socket. The socket consists of a shallow groove running dorsolaterally from the middle of the segment to a point just below the large papilla with the deepest part farthest inward. On the fourth appendages the peg is placed on the distal edge of the basis near the origin of the exopod as a slight fingerlike papilla with the tip turned mesially, a second mesial papilla bends outward to meet it. The usual chitinous ridge runs obliquely around the base; natatory lobe is much reduced. The exopod is attached to the basis by a bent kneelike portion, thus separating the two rami considerably.

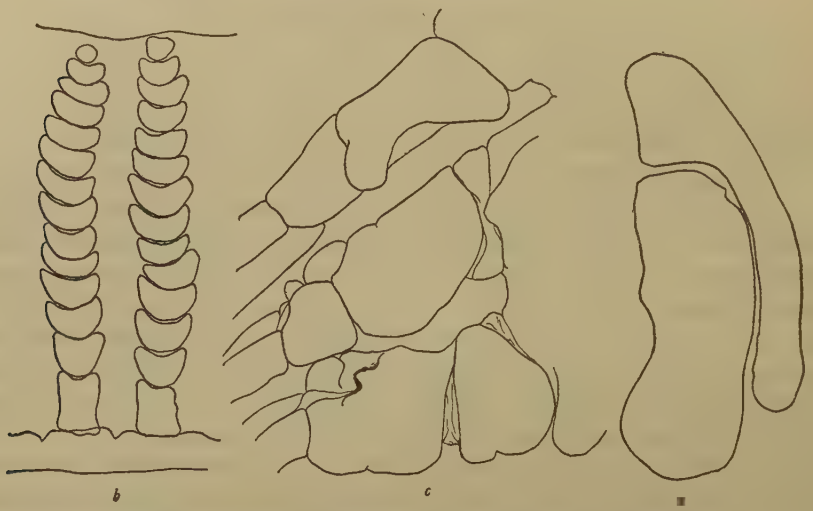

FIGURE 22.—*Argulus stizostethii: a,* Respiratory areas; *b,* ribs of suction cups; *c,* male accessory organs of second, third, and fourth legs.

Females have been reported to 12 mm. and males to 8.5 mm. They have been reported from the wall-eyed pike (*Stizostedion vitreum*), Niagara River, Buffalo, N. Y.; *Cynoperca canadensis*, Fairport, Iowa; *Coregonus* and *Acipenser fulvescens*, Le Claire, Minn.; brook trout, stickle-backs, perch, and suckers, Cape Breton Island, New Brunswick; *Esox masquinongy*, Vilas County, Wis.; skin of salmon, St. John, New Brunswick; swimming in Lake Erie.

The only difference that could be noted between *stizostethii* and *canadensis* is a slight variation in size and shape of body and some structures. These were no greater than variations within the species. There is some tendency for the occurrence of aberrant types of external respiratory areas in some specimens.

ARGULUS ALOSAE Gould

FIGURE 23

Argulus alosae GOULD, 1841, p. 340.—WILSON, 1902, p. 707, pl. 12, pl. 26, fig. 80; 1932, p. 17, fig. 6.

Carapace of female elliptical, male ovate; cephalic area very prominent; eyes comparatively large and set wide apart. Last thoracic segment is very wide and flares over the abdomen. Abdomen with points flaring, sinus shallow and wide, anal furcae minute and basal. Respiratory area reaching to the base of the suction cups, anterior small one slightly oblong, posterior one reniform (fig. 23, *a*).

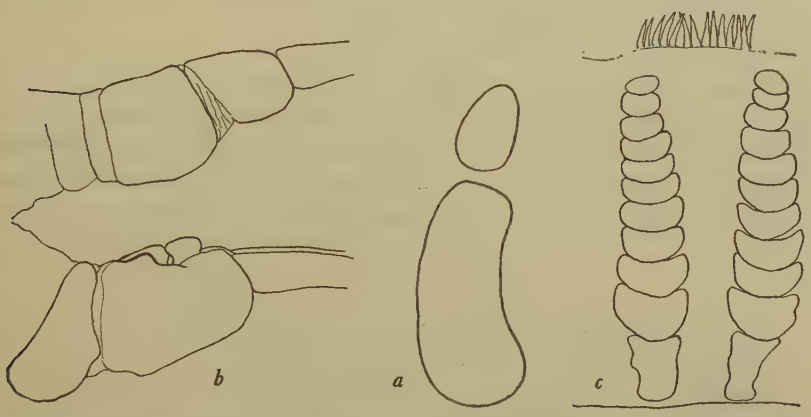

FIGURE 23.—*Argulus alosae: a,* Respiratory areas; *b,* male accessory organs of third and fourth legs; *c,* ribs of suction cups.

Antennae with anterior hook, weak, but lateral hook curved back some distance; spine on ventral surface fairly large, a large one at the base; a medium one at the base of second antennae, and a very large one at the midline. Second antennae comparatively long and slender. Suction cups large, ribs in rim made up of 10 to 12 imbricate plates with an elongate one at the base; marginal lappets long and narrow with setae at the ends (fig. 23, *c*). Second maxillae with wide basal plate, short, sharp teeth, widely separated, lateral one more widely separated than the others. Both pairs of postmaxillary spines pointed.

Swimming appendages without flagella, normal on the female except for a posterior bilobed coxa on the fourth appendages. First two pairs unmodified on male, peg merely a rounded papilla on the dorsal distal edge of the basis which fits into a posterior rounded cone-shaped lobe on the posterior surface of the third appendages, so that the papilla appears to overlap the socket when viewed either dorsally or ventrally (fig. 23, *b*).

The female measures up to 12 mm. and the male up to 6 mm. It has been found on the following hosts: *Clupea vernalis*, *Dorosoma cepedianum*, *Pomolobus pseudoharengus*, *P. strongylura marina*, and *Osmerus mordax* from the Woods Hole region; *Gasterosteus biaculeatus* in the Gulf of St. Lawrence; *Microgadus tomcod*, Base River, Nova Scotia; *Ctenolabrus adsperus*, Casco Bay, Maine, Great Egg Harbor, N. J., Key West, Fla., Patapsco River, Baltimore City, a fresh-water tow in the Shubenacadie River, Nova Scotia; and from the "toadfish," Shell Point, Fla.

ARGULUS SIAMENSIS Wilson

FIGURE 24

Argulus siamensis WILSON, 1926, p. 361, pl. 22.

Carapace ovate, reaching fourth appendages in the female, overlapping abdomen in the male; cephalic area narrow, posterior sinus broad. Abdomen elliptical, anal sinus deep, tips acute, slightly divergent. Respiratory areas with anterior one club-shaped and curved around posterior one, but slenderer than that of *stizostethii* (fig. 24, *a*).

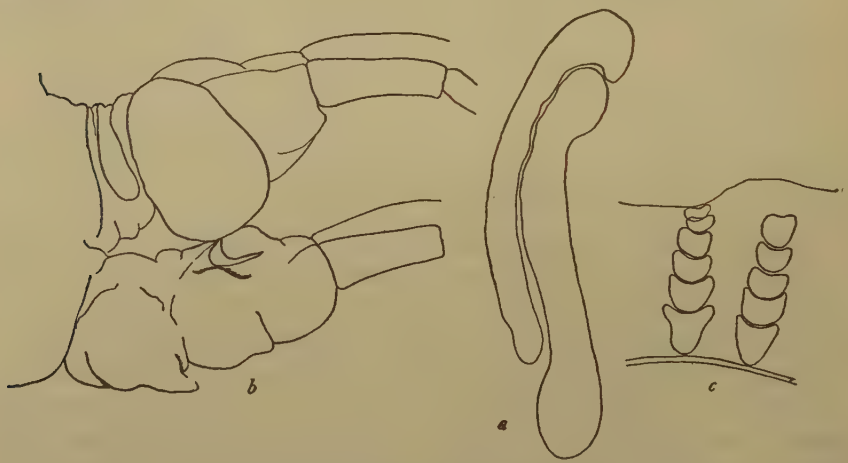

FIGURE 24.—*Argulus siamensis: a,* Respiratory areas; *b,* male accessory organs of third and fourth legs; *c,* ribs of suction cups.

Antennae with slight anterior knob, lateral hook long; ventral spine blunt, spine at base of first antennae long and blunt, that at base of second antennae small and transparent, postantennal spine long and blunt. First antennae relatively stout, second antennae very long. Second maxillae with broad basal plate, teeth broad and blunt, both pairs of spines near midline of body small and blunt. Suction cups with ribs of four or five imbricate plates and a longer basal one (fig. 24, *c*).

Swimming appendages with flagella. Fourth leg with posterior boot-shaped lobe in female, with toe drawn into a long fingerlike tapering process. On third appendages of male (fig. 24, *b*) the precoxa is slightly broadened; the coxa is rounded posteriorly where the socket is located, with a meager swelling anteriorly. On the fourth appendages is a posterior bilobed process with a scant lateral prolongation suggestive of the female. There is a small chitinous ridge around the peg. The peg itself originates a short distance back from the distal edge of the basis and projects ventrally against the anterior surface as a short fingerlike papilla.

The female is up to 6.55 mm. and the male up to 3.5 mm. Taken on *Cirrhina* sp. and *Trichopodus* sp. from fresh water at Bangkok, Siam.

ARGULUS INDICUS Weber

FIGURE 25

Argulus indicus WEBER, 1892, p. 544, fig. 1.—VAN KAMPEN, 1909, p. 447, figs. 5, 6.—WILSON, 1927, p. 1, pl. 1.

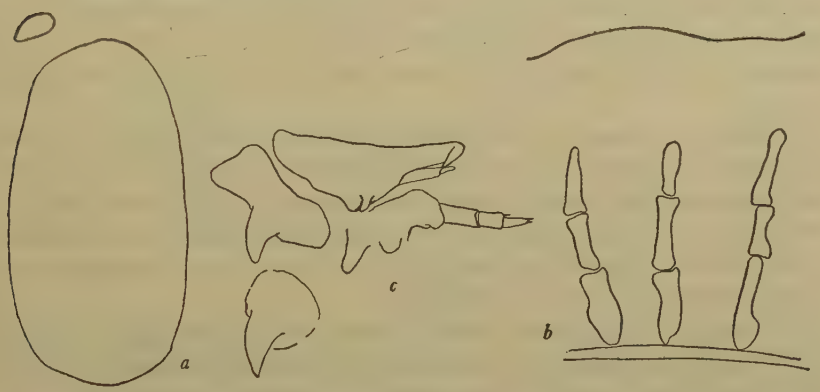

FIGURE 25.—*Argulus indicus: a,* Respiratory areas; *b,* ribs of sucking cups; *c,* antennae.

Carapace broadly rounded, alae covering over half of abdomen so that the whole animal is almost inclusive in a circle. Cephalic area prominent; dorsal ridges branched anteriorly; eyes small, without much pigment; abdomen wider than long, sinus deep, sides diverging, anal furcae subterminal. Whole animal dark colored, flecked with black. Anterior respiratory area minute, about opposite the second maxillae, posterior oblong area very large (fig. 25, *a*). Only the female is known. It measures about 7.75 mm. The host is *Betta* sp. from near Bangkok, Siam.

Lateral hook on first antennae short, without an anterior knob; basal and post antennal spines large; flagellum of first antennae

small, second antennae long (fig. 25, *c*). All spines are dark colored. Suction cups moderate, rim narrow, ribs composed of three rods, marginal lappets long (fig. 25, *b*). Second maxillae slender, basal plate with three large teeth; two pairs of prominent postmaxillary spines.

Thoracic appendages very long, first pairs with flagella; slight prominence with setae on the distal posterior surface of the coxa of third appendages on female; prominent boot-shaped natatory lobe on posterior of fourth appendages extending laterally as far as the base of the rami, with the heels pressed against the posterior end of the thorax; slight setose posterior lobe on the basis.

ARGULUS FLAVESCENS Wilson

FIGURE 26

Argulus flavescens WILSON, 1916, p. 349, pl. 61, figs. 7–12.—MUELLER, 1936, p. 807.
Argulus piperatus WILSON, 1920a, p. 149, figs. 1–7.

Carapace longer than wide, sinus more than one-third the length; abdomen ovate on female, elliptical on male, lobes rounded and often touching on the inner margins on the female, sinus giving the impression of being wider at the base; anal papillae basal, small, and rounded.

On the type there are lateral expansions into the carapace. These are called "lateral lobes of the stomach" by Wilson, but they are really expansions from the egg-filled ovaries. They occur only on gravid females, while those partially spent may have one side filled or only a few eggs remaining. Thiele noted these expansions on *A. africanus* in the Berlin Museum.

The anterior respiratory area is small and subtriangular, while the other is very large with a broader posterior portion (fig. 26, *b*). The females reach up to 6 mm., while the males are smaller.

First antennae with a slender lateral claw, anterior knob with a slight hook, flagellum about the length of lateral hook, tip biramous. Second antennae long, distal joints slender, spine at base; postantennal spines long and larger than others; ventral surface of distal segments armed with setae.

Suction cups with the ribs on the rim made up of four to six rods, the distal ones somewhat compressed (figure 26, *c*). Second maxillae with three blunt teeth on the basal plate, long setae on the pad of the basal disc (fig. 26, *a*). Postmaxillary spines fairly long. On southern specimens any or all may have a worn appearance.

Swimming appendages with flagella on the two anterior pairs. Second pair of male appendages with a posterior lobe on the ventral side of the precoxa, and the usual spinous pad on the coxa (fig. 26, *d*). Third pair of male appendages with a broader lobe on the posterior of the precoxa than on the preceding appendages and a long lobe over the coxa and basis that contains the socket. The peg is located on the distal anterior angle of the basal segment with a very broad base. It

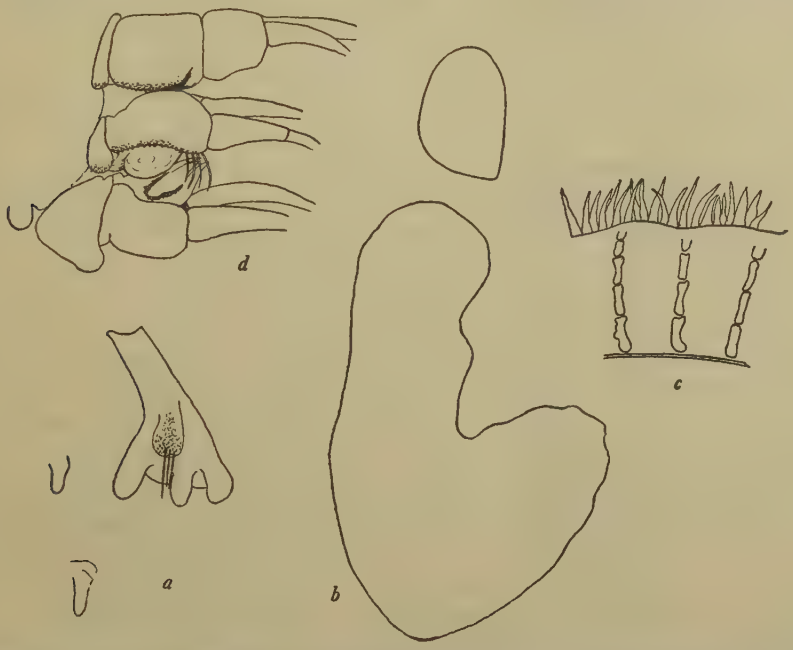

FIGURE 26.—*Argulus flavescens: a,* Basal plate of second maxillae and mesial spines; *b,* respiratory areas; *c,* ribs of suction cups; *d,* ventral view of male accessory organs of last three legs.

is divided longitudinally into two parts. The distal portion is slender, while the proximal portion is broad with a broad bluntly rounded tip and with transverse bands or chitinous ribs. On the ventral surface is a fleshy lobe directed obliquely toward the appendage much like that of *A. japonicus.* There is the usual chitinous ridge around the base of the peg, and a boot-shaped (in some cases more rounded) posterior lobe on the coxa. The total length of the basal segments of the three posterior appendages is progressively shorter toward the posterior. A large lobe is located at the opening of the ejaculatory duct. Both sexes are flecked with pigment.

The males of *piperatus* in the Museum are similar to Mueller's figure of *flavescens* and to specimens of the latter collected by myself in Florida. The distribution extends from Nova Scotia to Florida. They have been found on *Amia calva* and *Leptops olivaris* at Fairport, Iowa; free swimming in the Schubenacadie River, Nova Scotia; on *Hypentelium nigricans* from the Ohio River at Marietta; on *Huro salmoides* in the Myakka River and *Amia calva* in Lake Okeechobee, Fla., and on *Ameiurus nebulosus* and *Huro salmoides* at Welaka, Fla.

Additional Florida hosts reported by Dr. R. V. Bangham include:

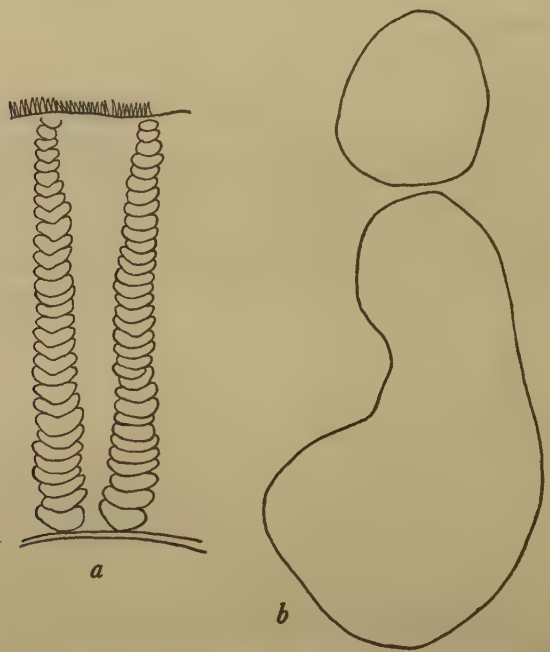

FIGURE 27.—*Argulus melanostictus: a,* Ribs of suction cups; *b,* respiratory areas.

Chub sucker (*Erimyzon sucetta sucetta*) at El Jobean; stump knocker (*Eupomotis microlophus*) at Naples, Englewood, and Lake Okeechobee; gold-spotted killifish (*Fundulus* sp.) at El Jobean; yellow bullhead (*Ameiurus natalis*), Myakka River; *Amia calva* at Joshua; marbled bullhead (*Ameiurus* sp.) from Lake Okeechobee and Englewood; largemouth black bass (*Huro floridana*) at Naples and Englewood; channel catfish (*Ictalurus punctatus*), Lake Okeechobee; and warmouth bass (*Chaenobryttus gulosus*) from a roadside ditch at Englewood. The list of hosts and the area of distribution are therefore very imposing.

ARGULUS MELANOSTICTUS Wilson

FIGURE 27

Argulus melanostictus WILSON, 1935b, p. 776, pl. 25, figs. 1–4.

Carapace about as wide as long, extending to third thoracic appendages; cephalic area projecting; eyes large, well separated; dorsal ridges bending sharply laterally ahead of the eyes; posterior sinus wide, sides flaring. Abdomen elliptical, lobes acute, sinus cut past center, tips flaring starting at middle of sinus; anal furcae basal. Body flecked with dark color. Respiratory areas include a rounded one near the suction cups and a posterior, larger somewhat J-shaped one posteriorly (fig. 27, *b*). Only the female of this species is known, and it reaches 8 mm. in length. It was taken in a tow at Monterey Bay, Calif., and there is a second record from Siam. Host unknown.

Antennae small, lateral hook short, anterior knob small, ventral median spine of lateral hook broad and blunt, spine at base of first antennae extremely large, that at base of second antennae long, postantennal spine extremely broad and blunt. Suction cups with edge supported by ribs composed of up to 30 or more apparently imbricate plates (fig. 27, *a*). Second maxillae have the penultimate segment enlarged and armed with spines. Basal plate very broad with short blunt teeth; spines at base of limb near midline on a broad prominence, second pair slenderer and more pointed and somewhat inconspicuously located.

Swimming appendages bearing flagella on anterior two pairs. Fourth pair with small boot-shaped natatory lobe on the coxa. Slight ventral posterior ridge on the coxa of the second and third appendages. Tactile papilla not apparent.

ARGULUS PUGETTENSIS Dana

FIGURE 28

Argulus pugettensis DANA, 1853, p. 1351, pl. 94, fig. 2a, b.—THORELL, 1865, p. 60.—WILSON, 1902, p. 711, pl. 15.—THIELE, 1904, p. 32, figs. 77–82.
Argulus niger WILSON, 1902, p. 714, pl. 18.

Carapace of female elliptical, covering appendages and extending onto the abdomen; cephalic area prominent with lateral sinuses deep. On the male the carapace is more nearly orbicular, covering only the third appendages; eyes small and widely separated. Abdomen of female ovate, lobes rounded, sinus very deep; on male elliptical, lobes pointed, sinus less than half the depth; anal papillae basal. The respiratory areas are composed of an anterior small rounded portion and a stout J-shaped larger area posteriorly (fig. 28, *b*). The male

openings are near two small rounded papillae, while the tactile papillae of the female are short and stout. The whole under surface of both sexes is very spinous.

Antennae comparatively small; anterior hook very conspicuous, flagellum very short; second antennae short; spines at base of first and second antennae very stout, postantennal pair stouter, those on ventral surface of lateral hook long and sharp. Suction cups on male about one-fifth the width of carapace, ribs composed of basal pedestal and 7 to 10 imbricate plates (fig. 28, *c*); those of female composed of approximately 16 imbricate plates (fig. 28, *d*). Second maxillae very stout and short, covered with armed padded areas; basal plate broad with teeth blunt, anterior pair of postmaxillary spines short and truncate, located on a large pad, posterior pair slender and blunt.

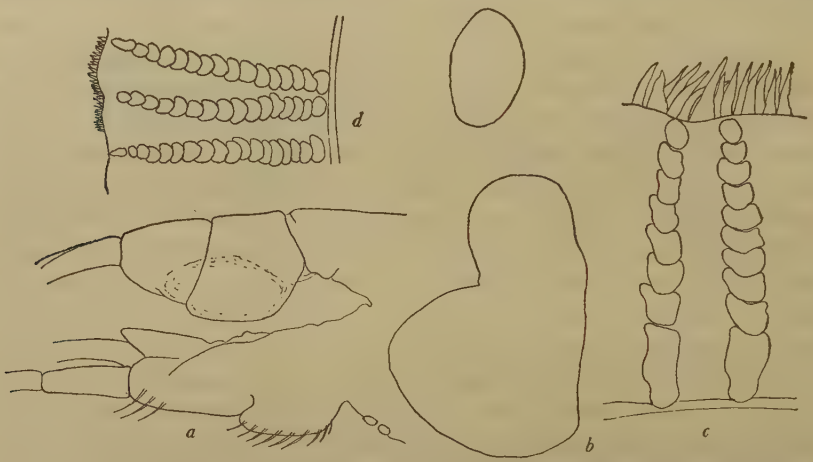

FIGURE 28.—*Argulus pugettensis: a,* Male accessory organs of third and fourth legs; *b,* respiratory areas; *c,* ribs of suction cups (male); *d,* ribs of suction cups (female).

Swimming appendages bearing flagella; boot-shaped natatory lobes of fourth pair very stout on female. Precoxa of male elongated on first three appendages; basal segment of second appendages unusually wide with a groove on the posterior surface, where it fits against the next appendage. On the third appendage a thin-walled voluminous sac extends the length of the coxa and part of the basis. Dorsally the opening of the socket extends about two-thirds the length of the sac. The fourth appendage has a boot-shaped natatory lobe posteriorly, and the usual chitinous ridge along the proximal side of the base of the peg. The peg is odd in that it is composed of a triangular lamina with the tip directed laterally and the base quite broad (fig. 28, *a*).

This is the only species studied where the ribs on the rim of the suction cups show any considerable sex differences. The female has been reported up to 18 mm. and the male 8 mm. This large difference

in size may account for the difference in the structure of the ribs of the suction cups. As far as can be determined *niger* is identical in every respect.

All specimens have been taken on the Pacific coast. They have been found free swimming and on the surf perch, blue perch (*Taeniotoca lateralis*), *Salmo irideus*, *Oncorhynchus kisutch*, *Hyperprosopon argeneus*, and *Cymatogaster aggregatus*.

ARGULUS FLORIDENSIS, new species

FIGURE 29

A single male specimen labeled *A. pugettensis* and found in U.S.N.M. vial No. 77810 is entirely different from typical *pugettensis* and will therefore be given a new name. It was collected by A. E. Verrill in 1884 at Key West, Fla. The host is not given.

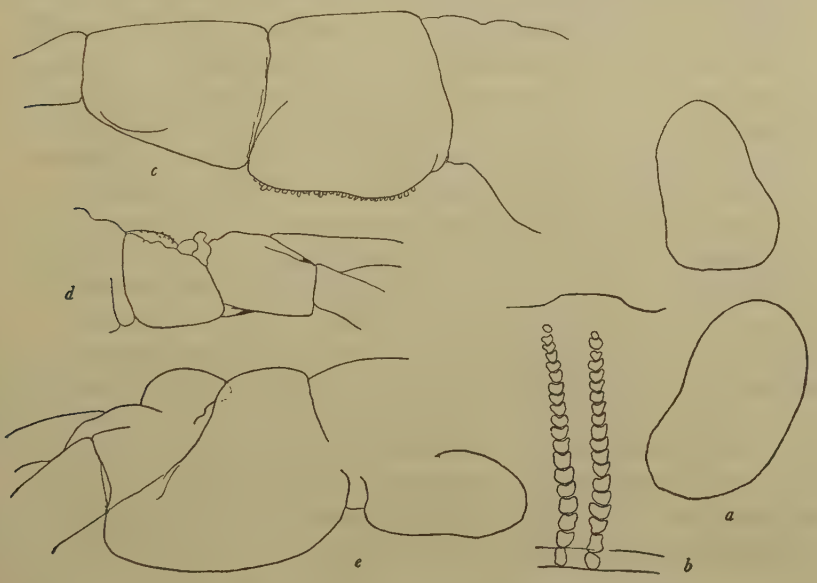

FIGURE 29.—*Argulus floridensis: a,* Respiratory areas; *b,* ribs of suction cups; *c,* second thoracic appendage (male); *d,* third thoracic appendage (male); *e,* fourth thoracic appendage (male).

Although the specimen is in poor condition, the following measurements were taken: Total length 5.85 mm., length of carapace 4.88 mm., width 4.28 mm., sinus 1.99 mm., abdomen 1.58 mm. long and 1.35 mm. wide with the anal sinus 0.98 mm.

The carapace is ovate, sinuses shallow, cephalic areas broad, eyes small, widely separated; alae reaching abdomen. Abdomen ovate, narrower at the top near the thorax, sinus deep, tips divergent, anal furcae small and basal. Dorsal ridges very stout, bowed inward

behind the eyes and diverging ahead of them. Respiratory areas well separated, almost equal in size and shape (fig. 29, *a*).

First antennae with an anterior hook; ventral mesial spine fairly large, basal spine of first antennae very large, spine on second antenna long and broad and postantennal spine very broad. These differ from *pugettensis* in that the spines at the base of the first antennae and near the midline are so very broad and the anterior hook is placed so far laterally on the lateral hook.

Suction cups about one-fifth the width of the carapace, with 18 or 19 imbricate plates in the ribs (fig. 29, *b*). This is very similar to the female *pugettensis*. Second maxillae slenderer and without so prominent spinous pads, with three broad blunt teeth, median one slightly broader than the other two, postmaxillary spines fairly long, both pairs pointing medially.

Swimming appendages without flagella. Second appendage with broadly bilobed lamella on posterior ventral edge (fig. 29, *c*). Third appendages with the dorsoanterior edge of coxa rounded proximally and armed with spines, ventral distal edge with an upright fingerlike papilla projecting anteriorly and a rounded papilla dorsal to it (fig. 29, *d*). On the fourth appendage there is a small rounded lamella on the posterior surface of the basis and a more broadly rounded bladelike lamella on the posterior surface of the coxa. The usual chitinous ridge extends obliquely across the basal segment with the peg originating on the dorsal distal end of the last basal segment and curved medially above this basal part like a curved finger (fig. 29, *e*).

There seems to be no indication of the socket from the ventral side of the animal, but on the dorsal side of the third appendage it may be seen as a saddled-shaped depression on the distal end of the basis, while the two rami are fused at their point of origin to form a broad base. This armature, the absence of flagella on the swimming appendages, and the two very nearly equal respiratory areas are all different from those of *pugettensis*.

ARGULUS BOREALIS Wilson

FIGURE 30

Argulus borealis WILSON, 1912a, p. 85, pl. 3.

Carapace slightly longer than wide, ovate; cephalic area prominent, eyes fairly large, alae reaching third appendages in female, fourth appendages in male. Abdomen elliptical; anal sinus shallow; anal furcae basal, tips diverging, testes extending almost full length of abdomen. Color almost lacking in the body except a brown band extending posteriorly from the edge of the cephalic areas paralleling the edge of the alae; dorsal surface of abdomen somewhat rusty in female; brown color on each side of testes in male. The respiratory

areas are composed of an oblong one anteriorly near the base of the second maxillae and smaller than the other, which is some distance posterior to it (fig. 30, *a*). The females measure to 8.5 mm. and the males to 4 mm. The hosts are *Lepidopsetta bilineata* and *Cymatogaster aggregatus* from Departure Bay, British Columbia.

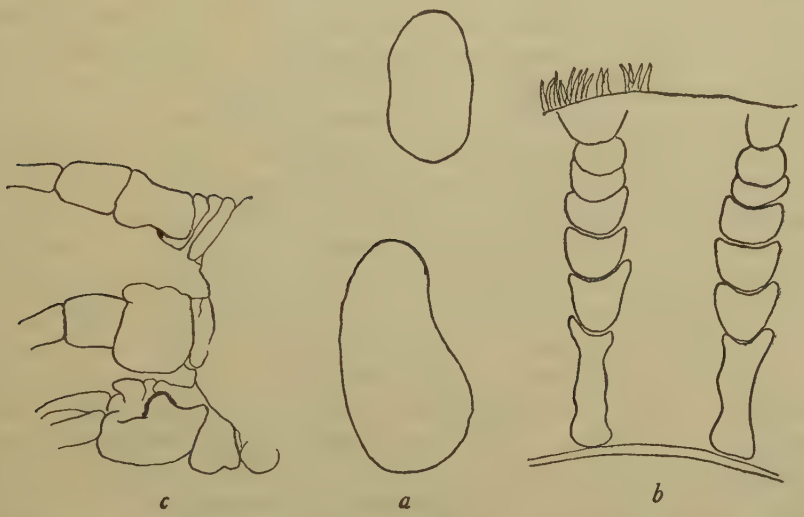

FIGURE 30.—*Argulus borealis: a,* Respiratory areas; *b,* ribs of suction cups; *c,* accessory organs of second, third, and fourth legs.

Suction cups with the rims supported by ribs composed of an elongate rod and four to six overlapping plates (fig. 30, *b*). Marginal lappets delicate. Second maxillae with a wide basal plate, teeth long and pointed; postmaxillary spines also long.

Antennae very trim; spines narrow, lateral hook sharp, anterior knob slender, ventral median spine prominent, spines at the base of the antennae and near midventral line long. Flagellum of first antennae longer than the lateral hook; second antennae extending almost to the edge of carapace.

Thoracic appendages without flagella. The posterior surface of the fourth appendage of the female with a somewhat bilobed fleshy prolongation of the coxa. Second appendage of male with a slight ventral posterior lobe (fig. 30, *c*). Third pair with an anterior rounded swelling on the coxa and a broadening of the same segment posteriorly where the socket is located. There is a posterior bilobed natatory flap on the coxa of the fourth appendages; the basal segments of the appendage are short and broad, with a ridge around the base of the peg on the distal anterior edge of the basis. The peg is a large, round prominence near the base of the exopod with a concavity around it. There is a bulbous papilla at the posterior end of the thorax near the male opening.

ARGULUS MEGALOPS Smith

FIGURE 31

Argulus megalops SMITH, 1873, p. 575.—WILSON, 1902, p. 706, pls. 11, 26; 1932, p. 16, fig. 5.
Argulus varians BERE, 1936, p. 579, pl. 1, figs. 11–16.

Carapace elliptical, male more rounded, in most instances reaching third appendages on both sexes, but on Florida specimens it may extend onto abdomen; cephalic area prominent, eyes large, well separated; posterior sinus broad, alae rounded; last segment of thorax broadened laterally, almost as wide as abdomen. Abdomen of female subtriangular, sinus shallow; male elliptical, connected to thorax by a narrow neck, almost as long as female, sinus shallower, anal furcae basal. The respiratory areas well separated, anterior one comparatively large, posterior with lobed margin (fig. 31, *b*). Female up to 7 mm. in length and male the same size. U.S.N.M. No. 60462, labeled *A. megalops* var. *spinosus*, is apparently not different from the regular species, except that there is less color and the spines on the ventral surface of the carapace show up better. Both have a very spinose under surface. Specimens labeled *A. varians* in the Bass Biological Laboratory differ only in a considerable variation of the size of the carapace. Other characters are identical.

Antennae slender, spines and hooks slender, lateral hook short, curved back on itself sharply, anterior knob long, with slight hook; spine on ventral surface of hook long and curved; slender spines present at base of first and second antennae and at midline; second antennae reaching almost to edge of carapace, many setae at each joint and on tip.

Suction cups small, separated somewhat, rim supported by ribs made up of an elongate rod and four to nine apparently imbricate plates (fig. 31, *a*). Second maxillae with broad basal plate having three slender widely spaced teeth; two postmaxillary pairs also slender.

Swimming appendages without flagella. Female with slender boot-shaped lobe with a broad heel and slender toe on posterior surface of fourth appendage. This varies somewhat in size. Tactile papillae slender and small.

Male third appendage with a fingerlike projection on the dorsal anterior distal edge of the coxa pointing anterolaterally, and on the posterior surface of the same segment is a large rounded lobe con-

taining the socket (fig. 31, *c*). The fourth appendages have a posterior flap, which is squarely truncate. There is the usual chitinous ridge surrounding the base of the peg. The peg is a rounded ball on a narrower neck at the distal anterior edge of the basis. Mesial to this is a triangular flap projecting anteriorly and turned ventrally at the tip. The top of the peg seems to be faceted. There is a broad papilla at the male opening between the bases of the fourth appendages.

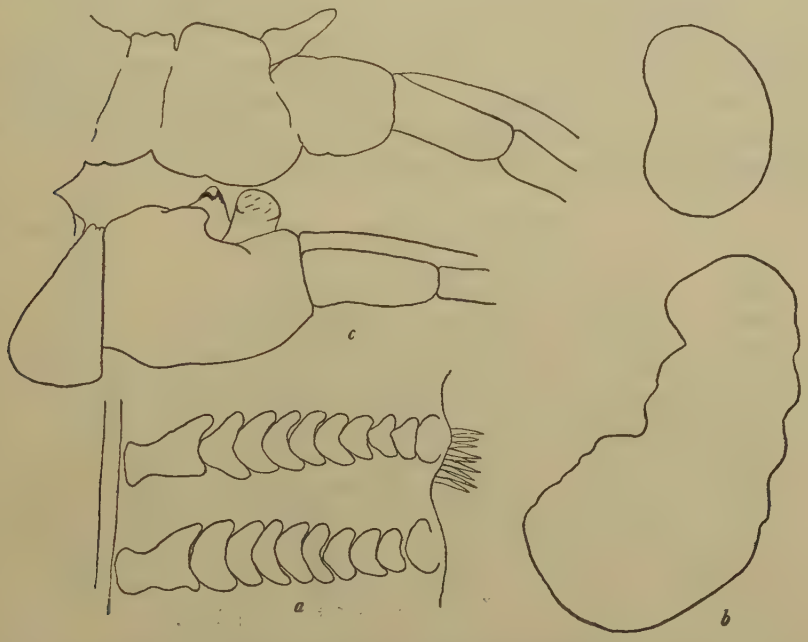

FIGURE 31.—*Argulus megalops: a,* Ribs of suction cups; *b,* respiratory areas; *c,* male accessory organs of third and fourth legs.

The host and localities have been reported as follows: *Myoxocephalus octodecimspinosus*, Salt Harbor, New Brunswick; *Pseudopleuronectes americanus*, *Paralichthys dentatus*, *Hippoglossoides platessoides*, *Lophopsetta maculata*, *Prionotus carolinus*, *Myoxocephalus octodecimspinosus*, *Lophius piscatorius*, *Microgadus tomcod*, and from tows in the Woods Hole region; and finally from the batfish (*Ogcocephalus* sp.), the pinfish (*Lagodon rhomboides*), the suckingfish (*Echeneis naucrates*), and the spiny toadfish (*Chilomycterus spinosus*), on the Gulf coast of Florida.

ARGULUS JAPONICUS Thiele

FIGURE 32

Argulus japonicus THIELE, 1900, p. 48; 1904, p. 39, figs. 94–98.—WILSON, 1902, p. 727.—TOKIOKA, 1936a, p. 334, pl. 21, figs. 1, 2.—YAMAGUTI, 1937, p. 781, figs. 1–9.

Argulus trilineatus WILSON, 1904, p. 651, figs. 34–38.—GUBERLET, 1928, p. 35, figs. 1–7.—MEEHEAN, 1937, pp. 288–292, pl. 1.

Carapace elliptical, covering third swimming appendages or reaching fourth; eyes well separated, cephalic area not very broad; sinuses shallow; abdomen small and spindle shaped; anal sinus deep, anal furcae basal, sides flaring on female, not on male. Anterior respiratory area small, subtriangular, posterior one large and reniform (fig. 32, *b*). The dorsal ridges are branched. Both males and females have been reported up to about 6 mm. in length.

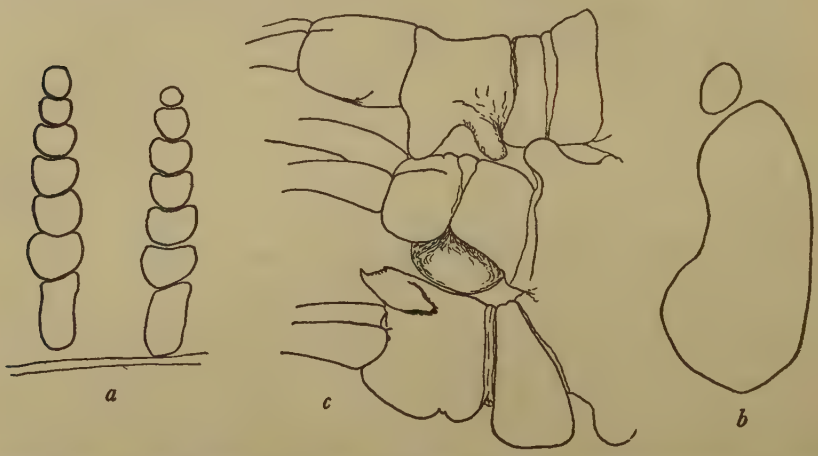

FIGURE 32.—*Argulus japonicus: a,* Ribs of suction cups; *b,* respiratory areas; *c,* male accessory organs of second, third, and fourth legs.

Antennae small, an anterior knob on the base of the first pair, spines at the base of both pairs and near the midline. Suction cups with an elongate basal segment and five to seven imbricate plates in the ribs (fig 32, *a*); marginal lappets about six or seven between the ribs. Second maxillae with broad basal plate having blunt teeth widely separated; spines near midline about the same size as the teeth.

Swimming appendages with flagella, posterior surface of coxa on fourth appendage of female with fleshy rounded lobe. On the male the second appendages have a bilobed posterior protuberance with truncate spines along edge. It is placed somewhat obliquely across the coxa with the mesial lobe more dorsal and the distal portion of lobe

somewhat longer. Between the second and third swimming legs is a slight spinous lobe on the lateral edges of the thorax directed from the base of the third thoracic appendage anteriorly (fig. 32, *c*). On the third and fourth appendages the basal segments are only about half as long as those of the two anterior pairs. The basal segment of the third pair is very broad, and a posterior lobe containing the socket extends about two-thirds the length of the segment. The peg is composed of a chitinous shovel-shaped lobe projecting laterally from the distal end of the basis, with a fleshy protuberance directed toward the appendage on the ventral side. Around the base of the peg is the usual ridge; the basis is enlarged posteriorly and a fleshy posterior lobe is located on the coxa. There is a large papilla at the ejaculatory duct on the end of the thorax.

The host in this country is the goldfish (*Carassius auratus*), and the species has been reported from almost every region where goldfish are found.

ARGULUS LATICAUDA Smith

FIGURE 33

Argulus laticauda SMITH, 1873, p. 574.—WILSON, 1902, p. 705, pl. 10.

Carapace longer than wide, alae reaching fourth appendages of male and abdomen on female; cephalic area broad and prominent, with deep sinuses, posterior sinus broad. Abdomen orbicular, about as wide as long; sinus about one-fourth the length of carapace and broad; anal furcae basal. The respiratory areas consist of an anterior smaller one opposite the maxillae and a posterior E-shaped larger one (fig. 33, *a*). Females have been reported to 7 mm. and males to 6 mm.

Lateral hook of first antennae short but turned back on itself; anterior knob long with slight indication of a hook at the end; ventral spine on base of hook stout, spine at base of antenna broad with a blunt end; flagellum just reaching beyond lateral hook. Second antennae long, almost reaching the edge of the carapace; spine at base very broad, postantennal spine very broad and long.

Suction cups small, rims supported by ribs made up of three or four straight rods (fig. 33, *b*). Marginal lappets very large. Second maxillae with narrow basal plate flaring widely into three truncated lobes, which may be squarely cut but usually appear to be worn in the center to give a slightly bilobed appearance. Postmaxillary spines short, broad, truncated, and fairly inconspicuous.

Swimming appendages with flagella. Female with small boot-shaped natatory flap on posterior surface of coxa on fourth appendages. Male accessory apparatus extremely complicated. Precoxa of

second appendages on ventral side with a narrow chitinous strip, which projects posteriorly beyond the edge of the appendage (fig. 33, *c*). Coxa extremely broad with a broad, flat lobe along the whole posterior side, which has a machete-shaped lobe on the distal part of the appendage projecting ventrally from the posterior lobe so that it stands out from the appendage. The third appendages have the combined basal segments telescoped. Posteriorly there is a chitinous lamina projecting toward the body similar to the narrower one on the anterior appendage; it is about three times as broad as the latter. The remainder of the segments form a saddle over the fourth appendage by means of a ventral lobe on the distal end of the coxa and a dorsal lobe proximal to it. The exopod is broad at the base

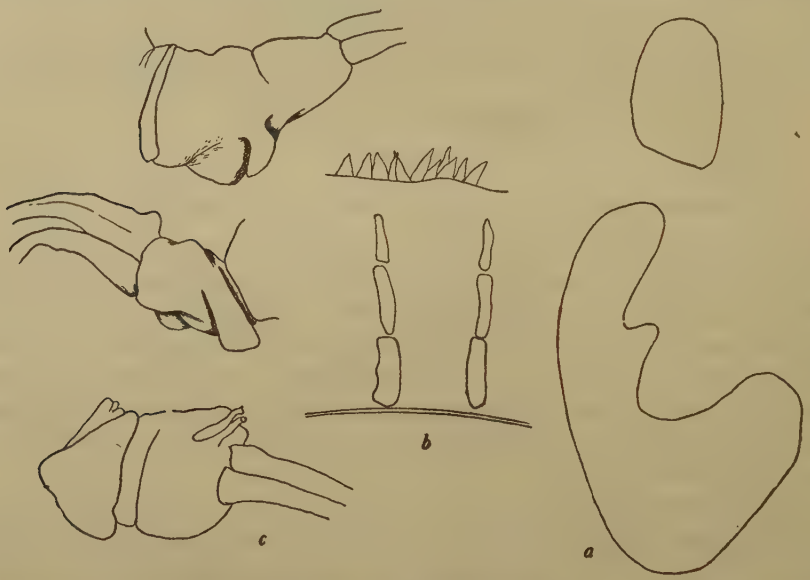

FIGURE 33.—*Argulus laticauda: a,* Respiratory areas; *b,* ribs of suction cups; *c,* accessory organs on last three legs of male.

with a large hump anteriorly which fits under the lobe of the anterior appendage. The fourth appendage also has short basal segments. Anteriorly the broad peg occupies more than half the space. It is projected out as a large papilla tipped on the distal edge by two chitinous cylindrical tips which extend down the side of the papilla. The posterior edge of the basis is expanded into a hatchet-shaped projection, while the coxa has a roughly boot-shaped one. The exopod is expanded slightly at the base.

This species has been collected in tows at Vineyard Sound, Mass.; on *Anguilla rostrata*, *Pseudopleuronectes americanus*, *Paralichthys dentatus*, *Microgadus tomcod*, *Myoxocephalus scorpius*, *Opsanus tau*,

all from the Woods Hole region; *Promicrops itaira*, Dry Tortugas; and from *Opsanus tau*, *Pteroplatea maclura*, and *Amphotistius say* in the Gulf of Mexico.

ARGULUS RETICULATUS Wilson

FIGURE 34

Argulus reticulatus WILSON, 1920b, p. 2, pl. 1.

Carapace elliptical; cephalic area slightly prominent, posterior sinus shallow and rectangular; eyes small, widely spaced; alae overlapping abdomen on female and about reaching it on the male. Abdomen ovate, anal sinus shallow and narrow. Anterior respiratory area subtriangular, posterior one very large and reniform (fig. 34, *b*).

FIGURE 34.—*Argulus reticulatus: a*, Rib of suction cup; *b*, respiratory area; *c*, accessory organs of second and third legs of male; *d*, fourth leg with peg.

Antennae short; anterior hook with broad base; spines present on the ventral surface of the lateral hook and at the base of the first and second antennae and near the midline of the body. The two latter somewhat stout. Suction cups with ribs composed of a series of rectangular rods, the distal one pointed (fig. 34, *a*). Maxillae slender, basal plate with three rounded teeth; first pair of maxillary spines pointed, second pair rounded.

Thoracic appendages with flagella. Second appendages of male with a bilobed protuberance on the posterior surface of the coxa. Third appendages with a large circular lobe containing the socket projecting posteriorly from the coxa, but overlapping part of the basis (fig. 34, *c*). On the fourth appendages is the usual natatory lobe on the posterior surface of the coxa. The peg is very much enlarged, but with the usual small tip. Extending along the ventral surface of the peg toward the appendages is a fleshy papilla somewhat like that on *japonicus* (fig. 34, *d*).

The female measures to 8 mm. and the male to 6 mm. The host is *Hydrocyon goliath* from the Congo River, Africa.

ARGULUS FUNDULI Krøyer

FIGURE 35

Argulus funduli KRØYER, 1863–64, p. 94, pl. 2, fig. 1.—WILSON, 1902, p. 710, pl. 14; 1932, p. 13, fig. 1.—THIEL, 1904, p. 34.

Argulus latus SMITH, 1873, p. 574.—WILSON, 1902, p. 704, pl. 9; 1932, p. 14, fig. 2.

Carapace about as wide as long; cephalic area broad and prominent; eyes large and well separated; posterior sinus broad, alae reaching third appendages on both sexes. Abdomen of male elliptical, half as wide as long, with the testes extending the full length to the sinus; female abdomen broader in proportion, with tips more widely separated; anal furcae basal. The respiratory areas are small and widely separated, somewhat circular in appearance; the anterior one ahead of the second maxillae and the posterior larger one behind the first swimming appendages (fig. 35, *b*).

The antennae are small, with a slight indication of an anterior knob; spine at base large, postantennal spines broader. Spine at base of second antennae smaller than those on first. Suction cups large, about one-third the width of the carapace; ribs in rim supported by 15 to 22 imbricate plates and a more elongate basal one (fig. 35, *a*). Marginal lappets very small. Second maxillae slender; basal plate broad and irregularly triangular, with one to three blunt teeth; the two pairs of postmaxillary spines lacking.

Swimming appendages without flagella; fourth coxa of female with a small, rounded posterior lobe, whole protopod broader than

on anterior appendages. Third appendages of male have an anterior triangular flap from the distal edge of the coxa extending over the basis; the posterior surface of the same segment is enlarged where the socket is located (fig. 35, *c*). The socket itself is merely a shallow cup with a fleshy lip around it on the posterior surface of the segment in contrast to the usual opening on the dorsal side.

The peg appears as a fingerlike lobe curled mesially, with a second lobe proximally and pressed up against it. They are both located on the dorsal side of the segment in line with the end of the exopod. There is a chitinous ridge around its base, as in other species.

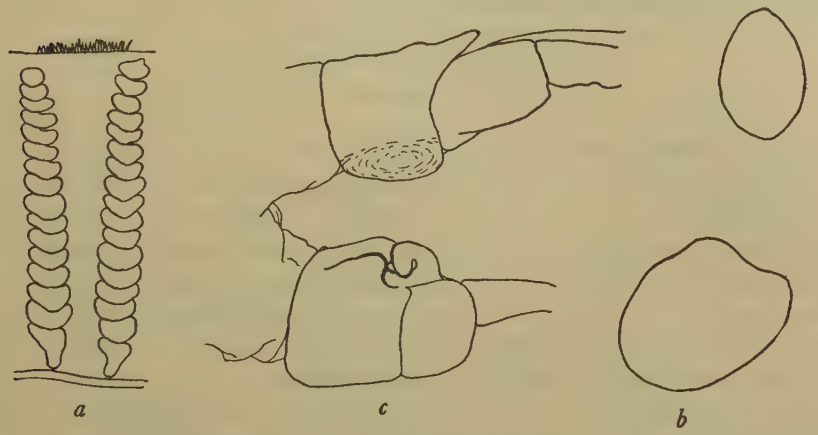

FIGURE 35.—*Argulus funduli: a,* Ribs of suction cups; *b,* respiratory areas; *c,* male accessory organs of third and fourth legs.

Smith's description of *A. latus* is not full enough to enable one to determine whether he has established a true species. The specimens of *A. funduli* and *A. latus* in the National Museum seem to be identical in every respect. Both have a slight lobe on the mesial side of the basal plate of the second maxillae, and they lack spines near the midline between them. They have 15 to 22 imbricate plates in the rim of the suction cups, with a slightly enlarged one at the base. The respiratory areas are similar on the two; the posterior lobe on the fourth swimming appendages of the female are alike. The antennae have a slight indication of an anterior knob on both species, with the spines at the base of the first antennae and the postantennal ones larger than the others. The carapace reaches or covers the third thoracic appendages. U.S.N.M. No. 60452 contained some immature males labeled *A. latus* along with some females. The males were immature so that the accessory copulatory apparatus was not developed far enough to tell whether there were any specific differences. It is therefore proposed that until the males are found these species be considered as synonymous.

A. latus has been taken in surface tows at Vineyard Sound, Mass., in a brackish pond on Chappaquiddick Island, Mass., and in Casco Bay, Maine.

A. funduli was described from specimens taken on *Fundulus ocellaris* near New Orleans, La.; others from many fish at Waquott Hole and Woods Hole, Mass., and Long Island Sound; from *Fundulus majalis* at Beaufort, N. C.; *Fundulus heteroclitus*, St. Andrews, New Brunswick; a brackish pool at Meveitta, Fla.; on *Menidia notata* and *Pseudopleuronectes americanus* from the Passamaquoddy region; and on *Lagodon rhomboides* from the Gulf of Mexico. The females measure to 5 mm. and the males to 4 mm.

ARGULUS VIOLACEUS Thomsen

FIGURE 36

Argulus violaceus THOMSEN, 1925, p. 185, figs. 1–15.

Carapace elliptical, covering second appendages on female and reaching third ones on male; posterior sinus broad, eyes widely separated; cephalic area prominent and sinuses deep. Abdomen of male subtriangular, with broadest portion near anterior end; almost rectangular on female, with narrow neck attached to thorax; sinus broad, uniform in width, anal furcae basal, rounded. The testes extend almost the full length of the abdomen.

Antennae arranged to accommodate them to the narrowness of the cephalic area. The lateral hook is pushed forward and bends back very far; anterior hook pushed mesially, very broad at base and long with a minute hook. A large spine located on the ventral surface of the lateral hook, spine at base of second antenna long and blunt, that at base of the first is broader and those near the midline very broad and blunt. Second antennae extending to the edge of the carapace.

Suction cups small and widely separated. Rim narrow with ribs composed of a somewhat J-shaped basal rod and an oblong distal one, marginal lappets blunt and rounded (fig. 36, *a*). Second maxillae slender, basal plate with three broad rounded lobes, and both pairs of spines near the midline rounded with spinous pads on them. Anterior respiratory area subtriangular located near suction cups, with the posterior one extending to the end of the alae (fig. 36, *b*).

Thoracic appendages with flagella, very stout and short on the female; thorax slightly widened between third and fourth pairs; on the male the coxa is slightly broader than the width of the second appendage. The third appendages are peculiar in that the basal

segments are only as long as the coxa of the second one; coxa with a bilobed papilla on the anterior surface; basis short and unmodified. The first segment of the endopod is very broad, with a spine in the middle of the ventral surface and a longer sharper one on the anterior distal surface at the base of the distal segment. The distal segment is curved, with long curved setae that fold over from both edges, which are peculiar in that they bend toward the posterior of the segment and are found on both edges instead of only one as in other species. The exopod originates on the dorsal surface of the basis and curves laterally reaching to the middle of the distal segment of the endopod. The socket can be seen from the dorsal side as a lobe rounded posteriorly from the coxa (fig. 36, *c*).

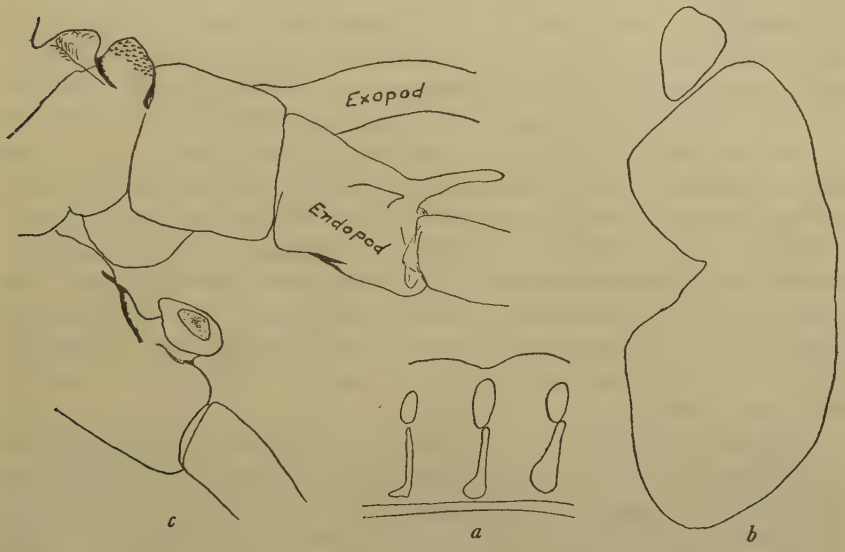

FIGURE 36.—*Argulus violaceus: a,* Ribs of suction cups; *b,* respiratory areas; *c,* accessory organs of third and fourth legs of male.

The fourth appendages have a slight rounded lobe on the posterior of the coxa. Anteriorly there is a slight indication of a chitinous ridge around the base of the peg. The peg is a mounded, button-shaped, chitinous papilla, with a slight concavity on the top. The exopod originates on the dorsal side of the basis as on the third appendages, with a triangular flap over the peg, as seen from the dorsal side. The basal segments of the fourth appendages are covered by the abdomen.

The female is 6.5 mm. and male 5 mm. The hosts are *Pledostomus commersonii* from Uruguay and *Rhamdia quelea.*

ARGULUS SALMINEI Krøyer

FIGURE 37

Argulus salminei KRØYER, 1863–64, p. 89, pl. 1, fig. 1.
Argulus paulensis WILSON, 1924, p. 4, pl. 1, figs. 1–5.

Carapace wider than long, reaching third appendages on male and overlapping them on the female. Cephalic area prominent, sinuses shallow. Eyes light colored and widely separated; dorsal ridges divergent anteriorly, extending very far anteriorly toward the edge of the carapace. Abdomen of female wider than long, anal sinus one-fourth the length, seminal receptacles large; male abdomen longer than wide, anal sinus very shallow and broad, testes occupying most of the available space; anal furnace basal, elongate.

Antennae slender, slight knob on anterior of lateral hook, which is bent in an arc, distal end of flagellum opposed by a prominent seta; second antennae so slender that the basal segments grade into the distal ones, spines slight, chitinous protuberances almost absent at base of second antennae but larger on ventral of first antennae and at base and near midline of the body. There is not so great a differentiation of the segments of the antennae as in other species.

Suction cups with narrow rims, supporting ribs tapered and broken into 9 or 10 segments, marginal lappets numerous between the ribs (fig. 37, *c*). Second maxillae with broad basal plate slightly lobed, medial lobe somewhat longer and narrower; two pairs of postmaxillary spines conspicuous or not, but present at least as chitinous prominences.

Swimming appendages with flagella, which are very stout on the female and tipped with very long setae. Appendages of female normal, with a small, boot-shaped, natatory lobe on fourth. Second swimming appendage of male has the usual posterior bilobed lamella but with the proximal lobe abbreviated and the distal one elongate (fig. 37, *a*). The lobe enclosing the socket on the posterior of the third appendage is located dorsally over the groove dividing the basis and coxa, so that the location of the socket cannot be noted from a ventral view, because the opening is on the segment proper rather than on the lobe. The peg is a triangular prolongation of the anterior edge of the basis ending in a number of points; dorsally the end is an oddly shaped movable hook with a flat surface underneath. On the ventral surface of the peg is a fleshy papilla projecting medially much as in *japonicus*. The coxa has a small, boot-shaped, natatory lobe posteriorly, well armed with long setae. There is a broad papilla near the male opening.

The respiratory areas are composed of an anterior subtriangular smaller one and a posterior large one with a notch in the middle of

the mesial side (fig. 37, *b*). The females measure up to 8 mm. and the males to about half that size. The host is the "Italrirana" in Brazil. It is a fresh-water species.

Thiele (1904) showed a pair of spinous prominences on the anterior surface of the basis on the third swimming appendage. The specimens at hand have one prominent one on the dorsal side of this appendage, with the rest of the anterior appendage rounded to fit under the lobe or pad projecting from the posterior surface of the second appendage.

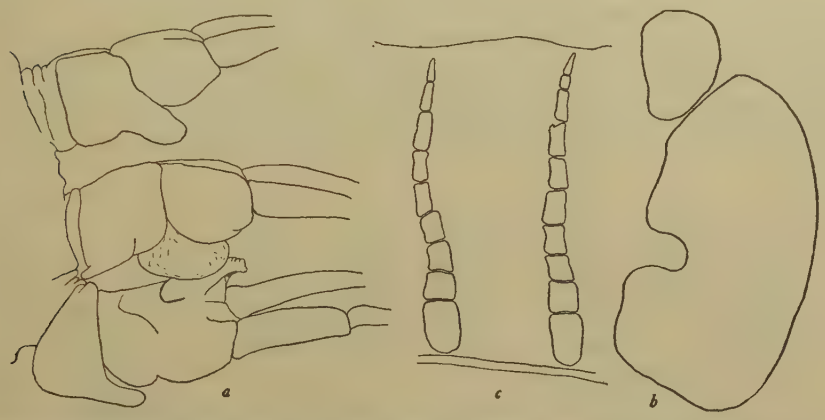

FIGURE 37.—*Argulus salminei: a,* Accessory organs of last three legs of male; *b,* respiratory areas; *c,* ribs of suction cups.

On the dorsal side the base of the coxa projects posteriorly as a rounded prominence, so that from a ventral view the tip appears as a spinous pad median to the rounded voluminous swelling enclosing the socket. The opening of the socket is an oblong slit, which is very long to correspond to the size of the large pad.

Two specimens labeled *A. nattereri* (Heller), No. 1261–91/435, are identical with *A. paulensis* Wilson. The largest of these was 10.4 mm. long. They do not fit Thiele's description of the type for *nattereri* in two particulars—the anterior protuberance on the first antenna is a knob rather than a hook, and the teeth on the basal plate of the maxillae are short and broadly rounded rather than long and slender.

Both groups of specimens seem to fit the description of *A. salminei* Krøyer, as given by Thiele, in every detail except one. He says that there are about seven segments in the ribs of the suction cups. The two groups in the Museum have about 16, and 9 or 10, respectively. Since these divisions are somewhat dependent upon the size of the animal and are the same in shape, the number of segments is not significant. The male accessory appendages of *paulensis* and *salminei* are alike. The former therefore becomes synonymous with the latter,

and the specimens labeled *nattereri* are really the same as these. No respiratory areas have been figured for any of these. They are, however, included in the present description.

ARGULUS AMERICANUS Wilson

FIGURE 38

Argulus americanus WILSON, 1902, p. 718, pl. 21, pl. 26, figs. 84–86; 1904, p. 627, figs. 1–21.

Carapace about as wide as long, overlapping the abdomen in both sexes, alae overlapping thorax and truncate on large females; cephalic area prominent, sinuses not deep. Abdomen subtriangular, about as wide as or wider anteriorly than the length; sinus one-fifth to one-fourth length of abdomen, sides diverging, anal furcae subterminal and large. The respiratory areas are peculiar in that the

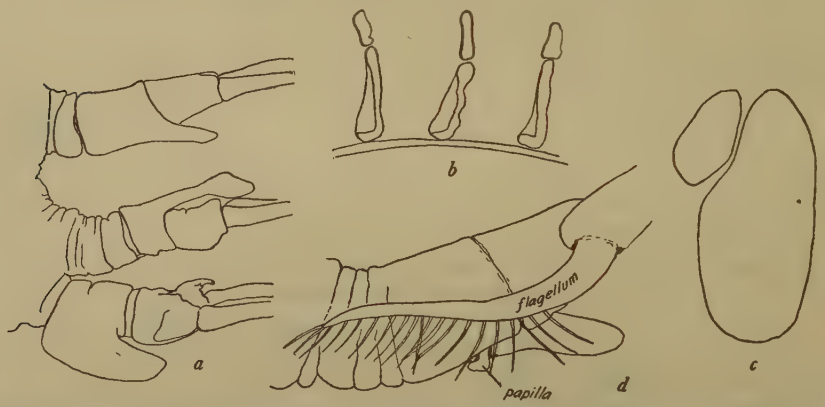

FIGURE 38.—*Argulus americanus: a,* Male accessory organs of last three legs; *b,* ribs of suction cups; *c,* respiratory areas; *d,* dorsal view of second male appendage.

smaller is oblong and located in a notch in the larger one, mesially and anterior to it (fig. 38, *c*). Females have been reported up to 12 mm. and males of about the same size.

Antennae deeply sunk into carapace, very characteristic since bases of first antennae are usually prolonged mesially into a knob; there is an extra spine between that at the base of the first antennae and the postantennal spine, making three pairs in a row. The lateral hook is bent posteriorly; base of segment enlarged into an anterior knob, rather than the usual more mesial one; ventral spine large; second antennae with large spine at the base; basal segments not very large, others progressively smaller and armed with setae.

Suction cups with rims supported by ribs composed of two or three elongate rods, interior ones longer than outer (fig. 38, *b*). Second

maxillae about normal, basal plate with the two mesial teeth more pointed than lateral broad one; postmaxillary spines blunt and rounded.

Swimming appendages with flagella. Female with boot-shaped lobe on posterior surface of fourth coxa; tactile papillae long and stout. Second appendage of male with a lobe on the posterior surface of the coxa prolonged laterally almost as long as the basis, a short flagellumlike papilla on the middle posterior surface of the coxa underneath the posterior ventral lobe (fig. 38, *d*). Third appendage with a club-shaped lobe on the anterior distal edge of the coxa extending over the basis to the exopod; on the posterior surface of the basis is a flat lobe with the socket opening on its dorsal surface (fig. 38, *a*). The peg, with an armed ridge around its base, is located on the basis of the fourth appendage; the posterior boot-shaped lobe extends laterally about to the distal end of the basis and is covered entirely by the abdomen.

From the host *Amia calva* it has been reported from Ann Arbor, Mich.; Lake Maxinkuckee and Kankakee River, Ind.; Fairport, Iowa; from *Umbra limi* at Fairport, Iowa; from *Amia calva*, Ocean Pond, Lake City, Fla.; and from *Esox nobilior*, Clayton, N. Y.

Approximately one-third of the type specimens of *americanus*, U.S.N.M. No. 20940, are spotted like *maculosus*. In the same way many specimens of the latter are unspotted, so that the color is not a specific character.

ARGULUS VERSICOLOR Wilson

FIGURE 39

Argulus versicolor WILSON, 1902, p. 716, pl. 20, pl. 26, fig. 83; 1904, p. 643, figs. 22–33.

Carapace only slightly longer than wide, alae overlapping abdomen slightly on the male and just reaching it on the female; cephalic area prominent, lateral sinuses not deep. Abdomen ovate in female, subtriangular in male; anal sinus very shallow, furcae subterminal and fairly large. Distinctive dark coloring along depressions in alae and posterior of cephalic areas, between dorsal ridges and along intestinal tract through abdomen. Wilson states that these are variegated in natural color. Smaller respiratory area rounded and located in a notch on the mesial side of the larger one (fig. 39, *a*). Females are reported up to 6 mm., males to 4.5 mm. The hosts and localities are as follows: *Esox reticularis*, Warren and Worcester, Mass.; Patapsco Relay, Md.; Lake Maxinkuckee, Ind.; "pickerel," Valdosta, Ga.

First antennae with anterior knob, broad ventral spine, and large spine at base; second antennae with broad spine at base; broad post-

antennal spine and an extra one between that and the one at the base of the first antennae, making three in a row.

Suction cups have ribs made up of an oblong basal plate and two to four somewhat oblong shorter ones (fig. 39, *b*). These differ from *maculosus* in that the distal plates are oblong rather than rectangular and the basal plate is long and narrow without a broad base. The second maxillae have long widely spaced teeth, with the two pairs of spines near the midline of the body stout and long, the posterior pair very near the basal plate. These teeth are slenderer than in *maculosus*.

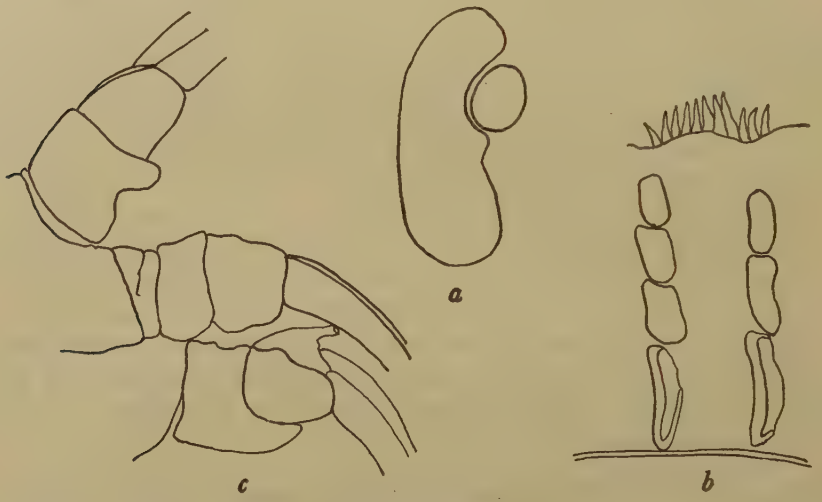

FIGURE 39.—*Argulus versicolor: a,* Respiratory areas; *b,* ribs of suction cups; *c,* male accessory organs of last three legs.

Flagella are present on the swimming legs. There is a slight lamella on the posterior of the coxa of the third appendages of the female; the usual natatory lobe on the posterior of the fourth appendage but without a heel; large females may have a lamella on the basis also, tactile papillae very long.

On the male the second appendages have the usual bilobed pad on the posterior ventral side of the coxa armed with short spines (fig. 39, *c*). On the third appendages there is a lamella on the posterior surface of the basis, with a rounded lobe on the coxa that accommodates the socket. Dorsally there is a large rounded papilla on this segment, with a groove running posteriorly to the opening of the socket. The fourth legs of the male have a posterior lamella expanded somewhat laterally over the basis. Anteriorly there is the usual chitinous ridge medially around the base of the peg, while the peg itself is pear-shaped, with a broad base and narrow tip projected

laterally. The exopods are distinguished from those of other species by being dark in contrast to the endopods.

ARGULUS MACULOSUS Wilson

FIGURE 40

Argulus maculosus WILSON, 1902, p. 715, pl. 19, pl. 26, fig. 82; 1907, p. 416, pl. 31, figs. 15–22; 1914, p. 354.

Carapace about as wide as long; sinuses sharp but not deep, alae reaching or covering third appendages; abdomen on male almost rectangular, but subtriangular on female; anal sinus fairly deep, with sides flaring somewhat. Tactile papillae very prominent. The respiratory areas consist of a small one in a notch on the mesial side of the larger (fig. 40, *a*).

Antennae with three spines along the midline, the posterior one broader and longer. There is an anterior hook on first antennae as compared with a knob on *americanus*, but the knob on proximal edge of basal segment of first antennae is not so prominent. There is a slight papilla above spine at base of second antennae. Suction cups supported by ribs composed of three to eight rods, as compared with two in *americanus* (fig. 40, *b*). Basal plate of second maxillae with long teeth, plate narrow, postmaxillary spines long.

Swimming appendages with flagella; fourth appendage of female with boot-shaped lobe with broad heel, extending beyond the abdomen; third appendages with slight posterior ridge, precoxae long, especially on male. Second thoracic appendages of male with the usual posterior lobe but extended laterally (fig. 40, *c*). It does not have the papilla under it that is found in *americanus*. Third appendage with anterior flap on coxa extending over basis; basis expanded posteriorly with socket. The peg is very broad at the base extending over the whole anterior surface of the basis; the tip is unusually large and turned somewhat anteriorly. The posterior lobe of the coxa is extended laterally around the basis.

There is considerable similarity between *americanus* and *maculosus* and between the females of *versicolor* and the other two. *A. maculosus* can be separated from *americanus* by the following points of difference: On the former the rounded anterior respiratory area is small and mesial, but on the latter it is large and at the anteromesial corner of the larger, more posterior one. The former has an anterior hook on the first antennae, while on the latter there is a knob. On *maculosus* the third spines at the midline near the antennae are longer and larger, and the mesial knob at the base of the first antennae is not very prominent. There are four to six rods in the sucking disks of *maculosus* and only two in *americanus*. The

teeth on the basal plate of the maxillae of *maculosus* are long compared with a lateral broad one in *americanus;* the extra flagellum-like papilla under the posterior lobe on the second thoracic appendages of the male of *americanus* is missing in *maculosus.*

A. versicolor differs from *americanus* in that it has respiratory areas like those in *maculosus.* It has an anterior knob on the antennae instead of the anterior hook, and the teeth of the basal plate on the second maxillae are slender.

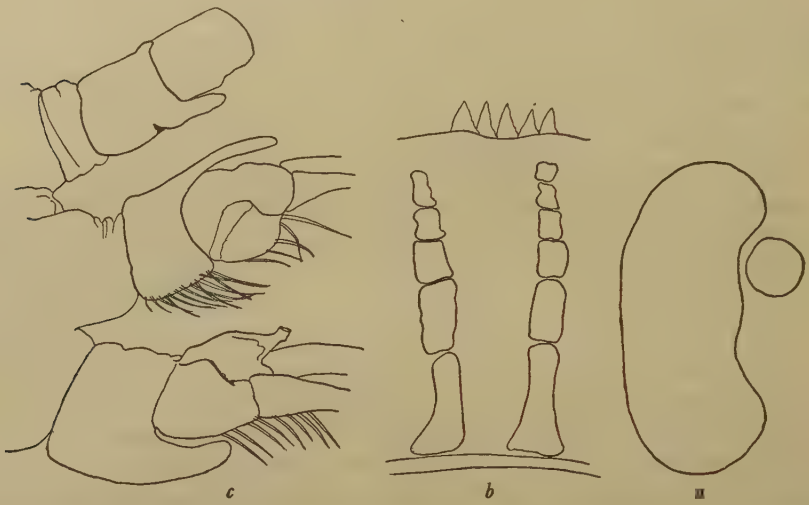

FIGURE 40.—*Argulus maculosus: a,* Respiratory areas; *b,* ribs of suction cups; *c,* male accessory organs of last three legs.

It differs from *maculosus* in that the three spines at the base of the antennae are about the same size. The rods in the ribs of the suction cups are composed of a narrow elongate basal and distal oblong segments as compared with a broad basal and rectangular distal segments on *maculosus.* The teeth on the second maxillae are very slender and widely spaced as compared with the closely spaced ones on *maculosus.* The male accessory apparatus is entirely different and characteristic.

This species has been reported from *Ameiurus nebulosus*, *A. natalis*, and *Ambloplites rupestris* from Lake Maxinkuckee, Ind.; and from *Ameiurus natalis*, Lost Lake, Ind. Females measure to 10 mm. and males to 7 mm. in length. This species also occurred in a collection sent me by Dr. Bangham from Woodmere, Fla., on the chub sucker (*Erimyzon sucetta*).

The type specimens for *maculosus*, U. S. N. M. No. 28937, are typical *americanus*, as well as No. 12226. Judged from Wilson's

description and figures (1902, pp. 715–716, pl. 19), he seems to have separated the species according to the presence or absence of pigment spots. On about one-third of the types of *americanus* one may note the typical flecks that he indicates as characteristic of *maculosus*. The remaining vials do contain specimens with the characters outlined above, some of which may be designated as types for the species. There is no such specimen as that from which he described the species and which was probably aberrant.

ARGULUS MISSISSIPPIENSIS Wilson

FIGURE 41

Argulus mississippiensis WILSON, 1916, p. 350, pl. 61, figs. 13–15; pl. 62, fig. 21; pl. 63.

Carapace subcircular, wider than long, alae somewhat truncate posteriorly so that lobes just about reach abdomen; eyes small and widely separated; abdomen one-fourth the total length of the body,

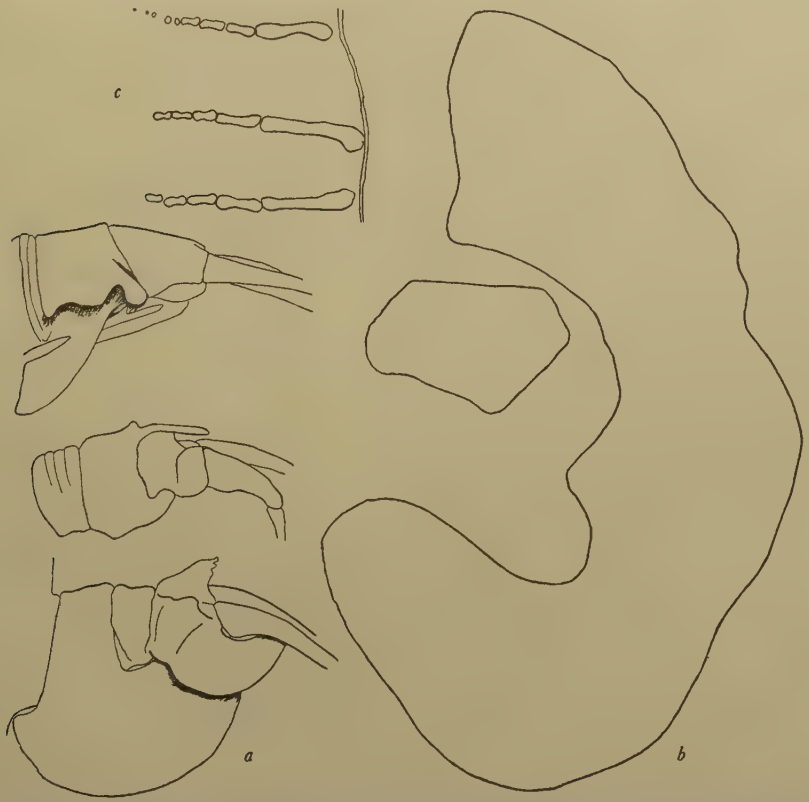

FIGURE 41.—*Argulus mississippiensis: a,* Accessory organs of last three legs of male; *b,* respiratory areas; *c,* ribs of suction cups.

roughly rectangular in shape; anal sinus deep, sides flaring on female and in contact on male, lobes pointed with anal furcae simulating a second more median tip to the lobes of the abdomen; anterior end of abdomen square. The whole effect of the animal is very flattened and leaflike, flecked with brown.

The lateral hook on the antennae is curved in an arc instead of being more sharply bent; anterior hook curved as well as the spine on the midventral surface of the hook. Spine at base of first antennae small, those near midline of body larger, all sharp. Tip of first antennae biramous, second antennae short.

Suction cups small, edge supported by ribs composed of three or four rods, with slight indications of others; about four triangular lappets on the edge of the disk between the ribs (fig. 41, *c*). Second maxillae short and stout, basal plate with sharp teeth; anterior pair of postmaxillary spines very small, posterior pair hardly discernible or lacking.

Swimming appendages with flagella on the two anterior pairs. Each of the first three pairs on the female with posterior ventral ridges or lobes on the coxa progressively larger toward the third one. Fourth appendage with a broadly rounded lamella on both the coxa and basis. Tactile papillae fairly large.

First swimming appendage of the male with a slight ridge across the posterior ventral edge of the coxa. Second appendage with a broad irregular lobe on posterior edge of coxa with distal edge longer. On the dorsal side the posterior edge of the coxa is prolonged into a machete-shaped flap directed toward the body over the base of the third appendages (fig. 41, *a*).

The third appendages have the precoxa somewhat enlarged; posterior ventral edge of the coxa lobed, with the distal edge prolonged laterally over the basis and the anterior distal edge prolonged as a flap over it. The toe of the posterior lobe covers the broadened portion of the basis, which contains the socket. There is a slight knob on the distal anterior end of the endopod.

There are two posterior lamellae on the fourth appendages similar to those of the female. The peg is very stout but ends in a narrow curved tip with a blade-shaped chitinous process under the tip. It is surrounded with a chitinous ridge, as in other species. The smaller rounded respiratory area fits into a concavity in the side of the semilunar large one that extends to the second maxillae (fig. 41, *b*).

The females have been reported to 19 mm. and the males to 12.5 mm. *A. mississippiensis* is about as large as *A. nobilis* but very much more flattened and expanded. The hosts are *Lepisosteus osseus* and *Cylindrosteus platostomus* from Fairport, Iowa.

ARGULUS CATOSTOMI Dana and Herrick

FIGURE 42

Argulus catostomi DANA and HERRICK, 1837, p. 297, pl. 1, figs. 1–11.—MILNE EDWARDS, 1840, p. 445.—THORELL, 1865, p. 60.—WILSON, 1902, p. 709, pl. 13.—THIELE, 1904, p. 25, figs. 53–58.

Carapace orbicular, usually wider than long, about reaching abdomen; abdomen relatively small, rounded, with sinus one-fifth to one-third the length. First antennae without spine at the base or on ventral surface of hook; anterior knob present, flagellum with seta opposing the distal segments; second antennae without a spine at the base, spine present near midline of body. The respiratory areas are composed of the smaller rounded one set in a notch mesially, about the middle of the larger, and about opposite the second maxillae (fig. 42, *a*). The females have been reported up to 12 mm. long and the males to 6 mm.

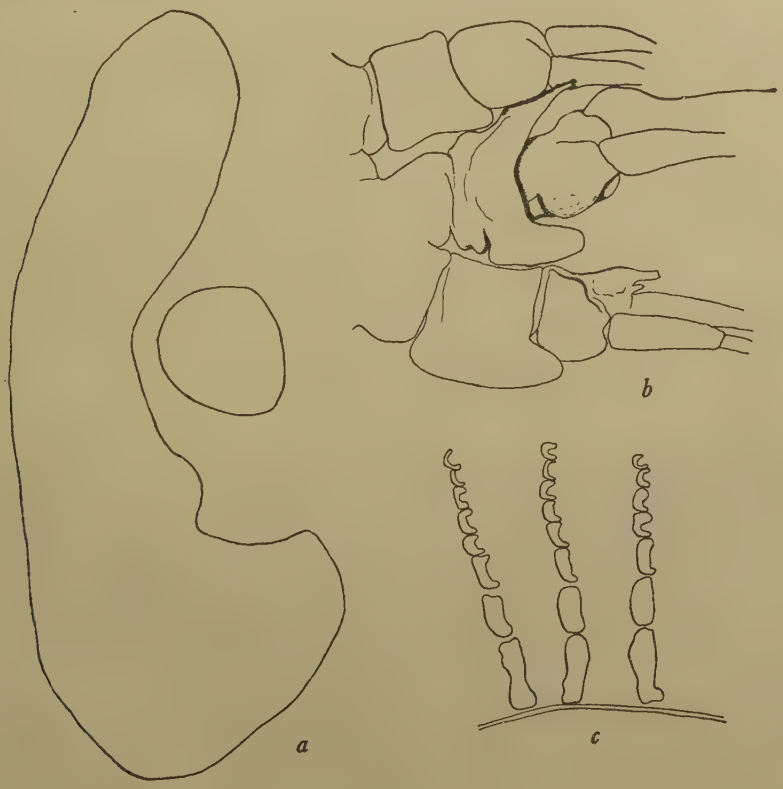

FIGURE 42.—*Argulus catostomi: a,* Respiratory areas; *b,* male accessory organs of last three legs; *c,* ribs of suction cups.

Suction cups supported by a series of seven to nine short rods becoming progressively smaller toward the edge of the rim, distal ones with only one side of rod thickened giving a C-shaped effect (fig. 42, *c*). Second maxillae stout, basal plate broad with three (sometimes two or four) broad stout teeth on the edge, lateral tooth stouter than others; the usual two pairs of postmaxillary spines absent.

The swimming appendages have flagella. Female with a flat lamella on the basis of the fourth appendages and a somewhat boot-shaped lamella on the coxa. There is a slight widening of the coxa of the third appendage to form a posterior ridge.

Second appendage of male has the usual posterior armored pad on coxa, which is peculiar in that it is highest on the distal end of the coxa and forms a saddle to fit over the next appendage. The third appendage has a flap on the anterior distal edge of the coxa extending over the basis to the exopod (fig. 42, *b*). From the posterior of the same segment extends a battle-ax-shaped flap over the fourth appendage and laterally over the basis covering the lobe containing the socket. The exopod has a knee at the base. The fourth appendage has the usual peg with a small prolongation to form the tip which is somewhat enlarged with a ridge around the base. The posterior surface of the coxa is prolonged into a boot-shaped flap.

This species has been taken on carp (*Cyprinus carpio*) at Fairbury, Ill.; from *Erimyzon sucetta oblongus* at Warren, Mass.; *Catostomus commersonii* at New Haven, Conn., Woods Hole, Mass., and Lake Champlain and Oneida Lake, N. Y.; and on *C. commersonii*, *C. nigricans*, and *C. catostomus* in Lake Maxinkuckee, Ind. In Connecticut and Massachusetts it was found in brackish water, but in fresh water elsewhere.

ARGULUS APPENDICULOSUS Wilson

FIGURE 43

Argulus appendiculosus WILSON, 1907, p. 419, pl. 32, figs. 23–30.
Argulus biramosus BERE, 1931, p. 428, figs. 1–7.

Carapace slightly longer than wide, reaching abdomen in male, shorter on female; cephalic area not prominent. Abdomen spindle-shaped, lobes pointed; anal furcae almost basal, diverging laterally and truncated; sinus about half the length of the abdomen. The respiratory areas consist of a small mesial rounded one fitted into a notch in the larger lateral one (fig. 43, *b*). The male has been reported up to about 10 mm. in length and the female considerably larger.

First antennae with no anterior knob, no spine on ventral median surface or at base; flagellum biramous. Second antennae with no spine at base, spine near midline long and blunt, flagellum well sup-

plied with setae. Suction cups about one-fifth width of carapace, rim supported by ribs with two segments, edge with truncated lobes armed with delicate setae as opposed to triangular lobes of other species (fig. 43, *a*). Second maxillae with blunt teeth and two pairs of blunt postmaxillary spines near midline.

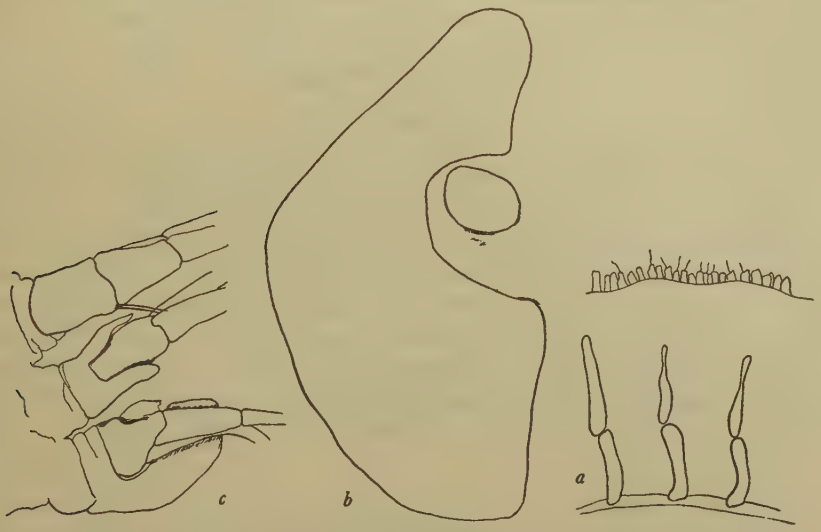

FIGURE 43.—*Argulus appendiculosus: a,* Ribs of suction cups; *b,* respiratory areas; *c,* male accessory organs of last three legs.

Swimming appendages with flagella, female with boot-shaped lamella posteriorly, which extends beyond the margin of the abdomen; on the male the lamella is prolonged and turned anteriorly so that the end is parallel with the anterior edge of the fourth appendages. The second appendage of the male has a broad lobe on the posterior ventral edge of the coxa, which is slightly prolonged laterally with long setae on it (fig. 43, *c*). On the third appendage the coxa has a triangular lamella extending over the basis and a posterior one also projecting laterally. The posterior surface of the basis beneath the lateral lobe of the posterior lamella is slightly enlarged to accommodate the socket with its opening directed dorsally. The basal joint of the endopod of the fourth appendage is broad and the terminal joint abbreviated on most mature males. The peg consists of a typical pear-shaped organ with a narrow tip directed laterally; around the base is the usual chitinous ridge running obliquely across the basis; posteriorly this segment is rounded into a lobe. The posterior lamella has already been mentioned.

The hosts and localities are as follows: Sucker (*Catostomus* sp.), Montpelier, Vt.; *Ictalurus punctatus*, grunt, Cumberland Falls, Ky.;

Micropterus salmoides, *Ictiobus cyprinella*, *I. bulbalus*, Fairport, Iowa; *Dorosoma cepedianum*, *Promoxis annularis*, *Roccus chrysops*, yellow perch (*Perca flavescens*), Little Star Lake, Wis.; *Catostomus commersonii*, Shenandoah River, Strasburg, Va.; *Ameiurus nebulosus* in Lake Erie; and on catfish in Lake Dallas, Tex.

The remains of specimens of *biramosus* in the U. S. National Museum are identical in every respect with *appendiculosus*.

ARGULUS LEPIDOSTEI Kellicott

FIGURE 44

Argulus lepidostei KELLICOTT, 1877, p. 214, figs. 1, 2.—WILSON, 1902, p. 712, pl. 16; 1916, p. 351, pl. 62, figs. 16–19, pls. 64, 65.—THIELE, 1904, p. 27.

Carapace elliptical, covering third appendages on female, almost to abdomen of male; abdomen ovate, broad at top on male, covering base of fourth appendages of both sexes; anal sinus deep, anal furcae over halfway from base, tips rounded. The respiratory areas extend only as far forward as the second maxillae. The smaller one is set in a notch in the upper mesial side of the larger with a second notch below it and a widened posterior portion (fig. 44, *b*).

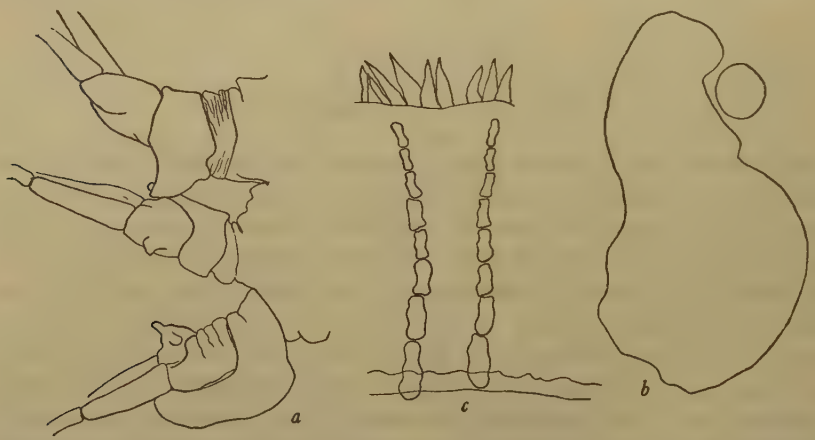

FIGURE 44.—*Argulus lepidostei: a*, Male accessory organs of last three legs; *b*, respiratory areas; *c*, ribs of suction cups.

First antennae with the lateral hook curved back, the anterior hook and midventral spine present, but no spine at the base. The tip of the flagellum is opposed by a slender branch. A larger spine is located at the base of the second antennae and a very large one near the midline of the body. The basal segments are not very stout. The suctions cups are large and close together; rims supported by ribs made up of a series of eight or nine short rods progressively smaller

toward the edge (fig. 44, *c*). Marginal lappets long and slender. Second maxillae with a narrow basal plate, teeth standing out abruptly from it and very sharp. Two median pairs of spines very sharp, proximal tooth on plate more widely separated than other two.

Swimming appendages with flagella. Prominent boot-shaped lamella on posterior surface of fourth appendage of female, tactile papillae prominent and long. Male second appendages with a very broad thin lamella on ventral posterior edge of coxa extending considerably back over the next appendage with a lateral prolongation of distal edge. Third appendages with a long somewhat triangular flap on the anterior surface extending from the distal end of the coxa over the basis to the base of the exopod. The basis is rounded posteriorly where the socket is located; there is a slight protuberance on the ventral side of this segment. The fourth appendage has a boot-shaped lamella of considerable size without a heel. The peg is located on the distal edge of the basis near the origin of the exopod and is pear-shaped, with a broad base and a narrow short projection laterally (fig. 44, *a*). Around the base obliquely across the segment is a chitinous ridge armed with short spines. The male opening is indicated by a stout cylindrical papilla at the end of the thorax between the appendages.

Females have been reported up to 11 mm. and males to 8 mm. Found on *Cylindrosteus platostomus* and *Lepisosteus osseus* at Defiance, Ohio; Fairport, Iowa; New York Aquarium (probably from Southern States); Buffalo, N. Y.; Kingston (State not indicated by Thiele); and Put-in-Bay, Ohio. Specimens were collected at Reelfoot Lake by Dr. C. L. Baker from the short-nose gar (*Lepisosteus* sp.). Dr. Bangham collected them in Florida on the spotted gar (*Lepisosteus* sp.) at Naples and in the Everglades Canal at Woodmere and Englewood.

ARGULUS NOBILIS Thiele

FIGURE 45

Argulus nobilis THIELE, 1904, p. 28, figs. 64–76.
Argulus ingens WILSON, 1912b, p. 233, pl. 30, pl. 31, fig. 7.
Argulus nobilis var. *ingens* WILSON, 1924, p. 2.

Carapace elliptical; cephalic area prominent in male, not so prominent in female; sinus extending to the middle of carapace or beyond; alae reaching to the edge of the abdomen. Abdomen heart-shaped in female, with anterolateral projections in male; anal sinus extending almost to middle of abdomen in male, reaching middle in female; tips of abdomen pointed, sides of sinus flaring; anal furcae one-third

to one-half distance to the base of sinus. Respiratory area as in figure 45, *a*.

First antennae with anterior hook and a ventral spine, none at base; flagellum with biramous tip, one branch secondarily branched; second antennae with spine at base; third spine near midline.

Suction cups with 12 to 14 segments in ribs supporting the rim (fig. 45, *b*). Second maxillae stout, rounded papilla on posterior ventral surface of third joint opposing claws of terminal joint on male; basal plate with three sharp teeth, papilla small and round, armed with long setae; two pairs of postmaxillary spines sharp.

FIGURE 45.—*Argulus nobilis: a,* Respiratory areas; *b,* ribs of suction cups; *c,* accessory organs of last three legs of male.

First two pairs of swimming legs with flagella; anterior distal end of proximal segment of endopod with a fingerlike projection; boot-shaped lamella on posterior coxa of fourth legs of female, lamella merely prolonged laterally on the male. Male first appendage with posterior lamella on coxa and a row of setae along posterior ventral edge; second appendage with usual bilobed lamella on coxa but distal end with perpendicular papilla, proximal part of lamella saddle-shaped from a lateral view (fig. 45, *c*); coxa of third has a long finger-like flap extending from the anterior distal edge of the segment over the basis to the expod; posteriorly the coxa is fringed with long setae. The socket is indicated by a rounded pocket on the posterior margin of the basis; the endopod is bent posteriorly at its origin and bowed anteriorly toward the joint. The fourth appendage has a lamella bearing setae on the posterior edge of the coxa, which is prolonged

laterally almost to the base of the endopod. The basis has a slight posterior rounded prominence with a few setae. The peg is set firmly on the anterior distal edge of the basis near the base of the exopod. It has the usual chitinous ridge running obliquely across the segment around its base; two rounded papillae indicate the opening of the ejaculatory duct at the end of the thorax. On the thorax of the male between the second and third swimming appendages is a pair of triangular flaplike structures, with the points of the flap directed anteriorly on each side of the body near the base of the appendage.

Length of female up to 25 mm., males about 16 mm. The hosts are the alligator gar (*Atractosteus tristoechus*), from Louisiana, Texas, and Mississippi, and the long-nosed gar (*Lepisosteus osseus*), from Ocean Pond, Lake City, Fla.

ARGULUS BICOLOR Bere

FIGURE 46

Argulus bicolor BERE, 1936, p. 580, pl. 2, figs. 17–23.

Carapace longer than wide, rounding forward into lateral sinuses, cephalic area projecting forward prominently, posterior sinus broad; alae reaching fourth swimming appendages of female, extending onto abdomen in male; last thoracic segment broad, attached to abdomen by a slender neck; anterior respiratory area small, slightly oblong, posterior one about the same width, three times as long and slightly curved (fig. 46, *a*). Abdomen about one-third covered by carapace in male, anal sinus nearly half its length, papillae inconspicuous; anal sinus of female more than half the length of abdomen.

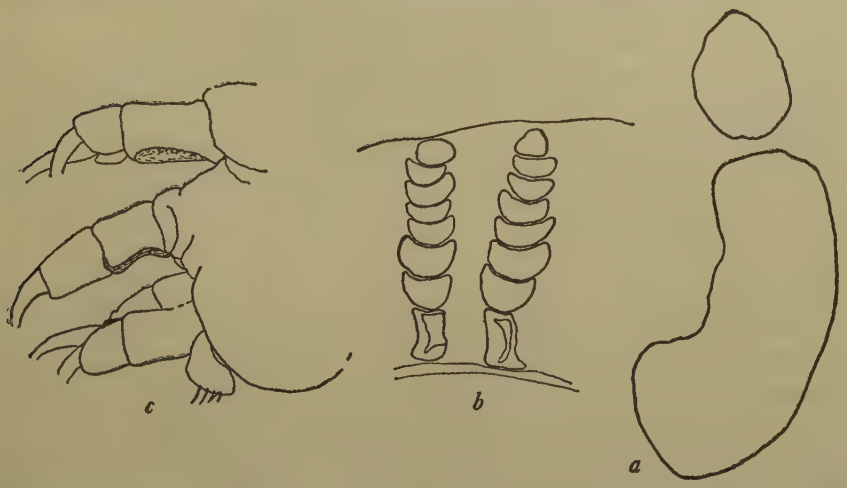

FIGURE 46.—*Argulus bicolor: a*, Respiratory areas; *b*, ribs of suction cups; *c*, male accessory organs of last three legs.

Antennae somewhat compressed with a prominent anterior hook, lateral hook curved back on itself; spine at base of first antennae larger than those at base of second antennae and on ventral surface of lateral hook, postantennal spines still larger, all three very broad; second antennae long. Suction cups occupying almost full width of carapace; ribs composed of 6 to 10 imbricate plates and an elongate basal segment (fig. 46, *b*). Second maxillae with two mesial spines of basal plate fairly sharp and short, lateral one broader with the spinous pad extending onto it. Postmaxillary spines very prominent.

Swimming appendages short, without flagella, very broad dorsoventrally; first, second, and third progressively longer, fourth short and stout, unmodified except broad coxa on male; female with bilobed natatory lobe on coxa; precoxa not apparent except natatory lobes, which are prominent and extend posteriorly in the male.

Slight concavity on coxa of second swimming appendages with minute spines around the edge. The socket is a large rounded concavity on the coxa of the third appendages that fits over a swollen anterior surface of the coxa on the fourth leg rather than being a true peg. The precoxa is indicated by a somewhat triangular swimming lobe closely attached behind the abdomen (fig. 46, *c*).

Taken on the needlefish (*Strongylura notata*) and sand bream (*Archosargus unimaculatus*) in Lemon Bay, on the Gulf coast of Florida.

ARGULUS FUSCUS Bere

FIGURE 47

Argulus fuscus BERE, 1936, p. 578, pl. 1, figs. 2–10.

Carapace elongate, lateral sinuses shallow, cephalic area well marked; carapace reaching onto abdomen; posterior sinus about one-fourth its length, very narrow. Anterior respiratory area oblong, posterior one considerably wider and flaring to double the width of the anterior portion about halfway back (fig. 47, *a*). In the male the abdomen is about one-third the total length, somewhat rectangular in shape, sinus shallow, sides flaring, anal furcae basal, testes very long, reaching sinus; abdomen oblong in female, with sinus reaching over half its length.

Antennae with a prominent anterior hook, tip of lateral hook curved back on itself, flagellum of first and second antennae extending beyond lateral hook, which is short. Ventral spine prominent, basal spines of first and second antennae much smaller than postantennal spines. Suction cups with ribs composed of 6 or 7 imbricate plates and a rectangular segment (fig. 47, *b*) in male and 12 to 14 in female, with the basal segment almost square. Second maxillae

with two mesial spines of basal plate narrow and blunt, distal one broad; postmaxillary spines long.

Swimming appendages about the same length, quite stout in male, elongate in female; without flagella. Two anterior appendages of male unmodified. Third one with a rounded knob on the dorsal anterior side of the coxa, basis elongate with the socket extending

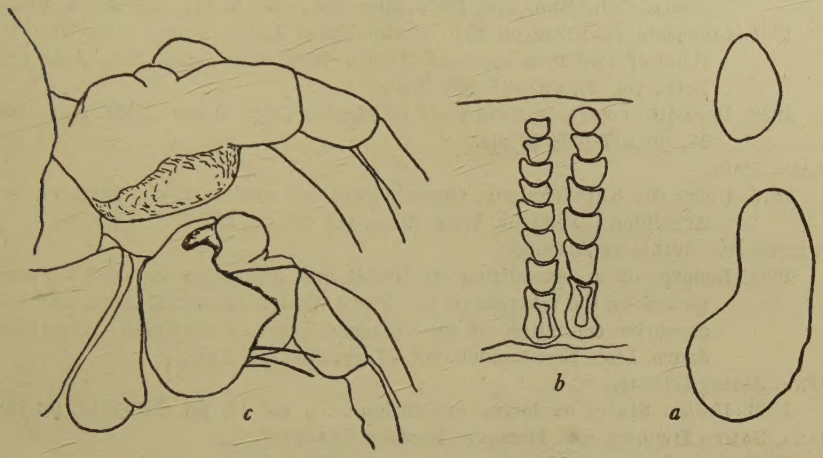

FIGURE 47.—*Argulus fuscus: a,* Respiratory areas; *b,* ribs of suction cups; *c,* male accessory organs of last two legs.

along the full length of the posterior edge, which is drawn out into a ventral flap. Fourth appendages of male very short and broad dorsoventrally. Peg a large knob on the anterior surface of the coxa; basis stout and horny, with a ridge forming a cup around the peg. Precoxa a triangular-shaped segment with base of triangle directed posteriorly and slightly lobed to form a natatory lobe (fig. 47, *c*); in female modified into a boot-shaped natatory lobe posteriorly.

Taken on hogfish (*Orthopristis chrysopterus*) and silver perch (*Bairdiella chrysura*) in Lemon Bay, Gulf coast of Florida.

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